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SPACE SCIENCES LABORATORY

APPLICATION OF REMOTE SENSING
TO SELECTED PROBLEMS WITHIN THE
STATE OF CALIFORNIA

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APPLICATION OF REMOTE SENSING
TO SELECTED PROBLEMS WITHIN THE
STATE OF CALIFORNIA

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CHAPTER 1

INTRODUCTION

Robert N. Colwell

CHAPTER 1 INTRODUCTION

Robert N. Colwell

The overall objective of work done under this grant is to demonstrate, by means of specific case studies, that information derived from the use of modern remote sensing techniques can lead to the development and implementation of more intelligent resource management measures than would otherwise be possible. Our case studies deal with applications that can be made of remote sensing to selected problems within the state of California.

Within California there are a great many state, county and local agencies that are concerned with such natural resources as timber, forage, soils, water, minerals, agricultural crops, fish, wildlife, and recreational resources. Several of these agencies have expressed a desire to use remote sensing techniques as an aid in solving their resource management problems. In almost every instance their basic need is for better and more timely inventories of these resources so that, at all times, they will have better information as to the amount, condition, and spatial distribution of each component of the entire "resource complex" within each portion of the area for which they have management responsibility. Given such inventory data, they can then determine, within each portion of the overall area, the cost-effectiveness of each of the various resource management alternatives that are available to them.

In many cases, there is insufficient knowledge on the part of the resource managers of how remote sensing might be applied, but they have stated that, given one or more appropriate demonstrations of such applications, they would then hope to make remote sensing an integral part of their overall resource management process. From among the many possible cases fitting this description, three are dealt with in this project, the objective being in each case to demonstrate the practical benefits of remote sensing through a combination of applied research and education programs. The three cases are (1) the mapping of fuels in relation to the management of brushlands and timberlands in Mendocino County; (2) the

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prediction of watershed runoff in relation to water storage and flood control in the area within which water resources are managed by the Kern County Agency; and (3) the defining and mapping of environmentally homogeneous units within the California Desert so that more intelligent management of each portion of that increasingly important area might be effected by the U.S. Bureau of Land Management, in cooperation with their colleagues in San Bernardino and Riverside counties.

The three "case studies" listed above are being performed by our remote sensing scientists on the Berkeley, Santa Barbara, and Riverside campuses, respectively, of the University of California. A description of progress made to date on those three case studies will be found in Chapters 2, 3, and 4, respectively, of the present Progress Report.

Three other preliminary studies are being made by our group: (1) Remote Sensing as an Aid to the Inventory of Bird Habitats (as reported in Special Study No. 1); (2) Remote sensing of Dipteran Breeding Habitats (as reported in Special Study No. 2); and (3) Remote Sensing as an Aid to California Citrus Crop Forecasting (as reported in Chapter 4).

An important objective in all of our studies is that of achieving "technology acceptance" by the resource manager to the point where resource management decisions are both made and implemented primarily on the basis of remote sensing-derived information. In many instances this is quite simply accomplished. In such instances there usually is only a single agency or resource manager, his informational requirements being simple and straightforward. But there also can be more complex cases involving several agencies, each being charged with managing the entire "complex" of natural resources within the area for which it has management responsibility and each having a somewhat different concept of priorities with respect to the products that might be derived from those resources. Such complexities have led to a concept known as Coordinated Resource Planning about which some mention was made in our Progress Report of May, 1977. Important considerations with respect to that concept will be found in Appendix A of this report.

As will be documented in Chapter 2, a significant amount of progress already has been made in our efforts to use remote sensing in relation to the inventory and management of brushlands and timberlands in Mendocino County, California. Partly because of that success there is growing

interest in the possibility of using our Mendocino County test area as one in which to demonstrate the validity and value of the Coordinated Resource Planning concept.

The remainder of this report consists, by and large, of a chapter-by-chapter account of the various case studies that have been mentioned in this introductory chapter.

CHAPTER 2

FUEL MAPPING IN RELATION TO THE MANAGEMENT OF BRUSHLANDS AND TIMBERLANDS IN MENDOCINO COUNTY, CALIFORNIA

Co-Investigator: Andrew S. Benson

Remote Sensing Research Program
Berkeley Campus
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CHAPTER 2

FUEL MAPPING IN RELATION TO THE MANAGEMENT OF BRUSHLANDS AND TIMBERLANDS IN MENDOCINO COUNTY, CALIFORNIA

by

Andrew S. Benson

Co-investigator: Berkeley Campus

1.0 Introduction

In California, as in most other areas where the population is increasing rapidly, the pressure upon various kinds of wildland resources also is increasing rapidly, thus requiring better and more current management plans. Throughout the state of California, wildland management agencies are charged with a two-fold responsibility: (1) producing various goods and services (timber, forage, recreation, etc.) and (2) protecting environmental quality (water, wildlife habitat, aesthetics, etc.). In order to effectively manage California's wildland resources and fulfill this two-fold responsibility it is necessary to set management objectives, acquire and analyze timely inventory data, and evaluate the impact and cost effectiveness of each feasible management action or proposed land use. As demonstrated in the present study, remote sensing can provide valuable inventory data, with the aid of which management decisions can be made.

This chapter constitutes a report on investigations being carried out in Mendocino County, California (Figure 1) by personnel of the Remote Sensing Research Program (RSRP), University of California, Berkeley Campus. These investigations deal primarily with the use of modern remote sensing techniques as an aid in wildland fuel mapping. The objective is to provide area-specific information that is needed for pre-fire suppression planning and for fuel modification actions. The two major types of remote sensing data that are being used are Landsat digital



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Figure 1. Location, Mendocino County in northern California. Investigations are being conducted here by personnel of the Remote Sensing Research Program, University of California, Berkeley Campus, to demonstrate the usefulness of remote sensing-derived data for planning and implementation of fuel management plans. For the location of specific study areas within Mendocino County, see Figure 2.

data and small scale U-2 aerial photography.

2.0 Work Done to Date

2.1 Historical Perspective

In February 1976, the Mendocino County Board of Supervisors, recognizing the need for a comprehensive fuel management plan, established the Fuel Control and Brush Range Management Committee (FMC). The primary mission of this committee, with representatives from county, state, and federal agencies, has been to develop and implement a fuel management plan in pilot areas throughout the county. The primary objective of fuel management in this area is to break up large homogeneous fields of brush into smaller brush-grassland mosaics. In this way, not only are fire hazards reduced, but the "edge effect" around brush fields is increased so as to provide more shelter and forage to wildlife and domestic animals. In addition, soil stability will improve if stands of grass can replace the decadent brush.

2.2 Involvement of the Remote Sensing Research Program

Personnel from the Remote Sensing Research Program with the support of NASA's Office of University Affairs have acted as technical advisors to the FMC since its inception. From the start it was recognized that some form of remote sensing data in combination with other forms of ancillary data would be needed as a base from which a management plan could be developed. Information acquired by means of remote sensing was needed because it was the type which could be (1) efficiently gathered for extensive inaccessible areas of the type encountered in much of Mendocino County, and (2) easily manipulated to meet both primary and subsequent secondary objectives relating to fuel management.

As a result of the first year's effort, an 80,000 acre pilot area east of Covelo (see Figure 2) was mapped by RSRP personnel into 10 major vegetation classes through the use of computer-aided analysis of Landsat digital data (Cosentino, et al., 1976). In addition to this vegetation map, output products included information with respect to soils, road networks, property boundaries, geology, and township-range grid, each compiled as an overlay to the vegetation map. Finally, the species composition of each vegetation class was quantified through the manual interpretation of large scale aerial photography, supplemented, as necessary, with limited amounts of direct on-site inspection.

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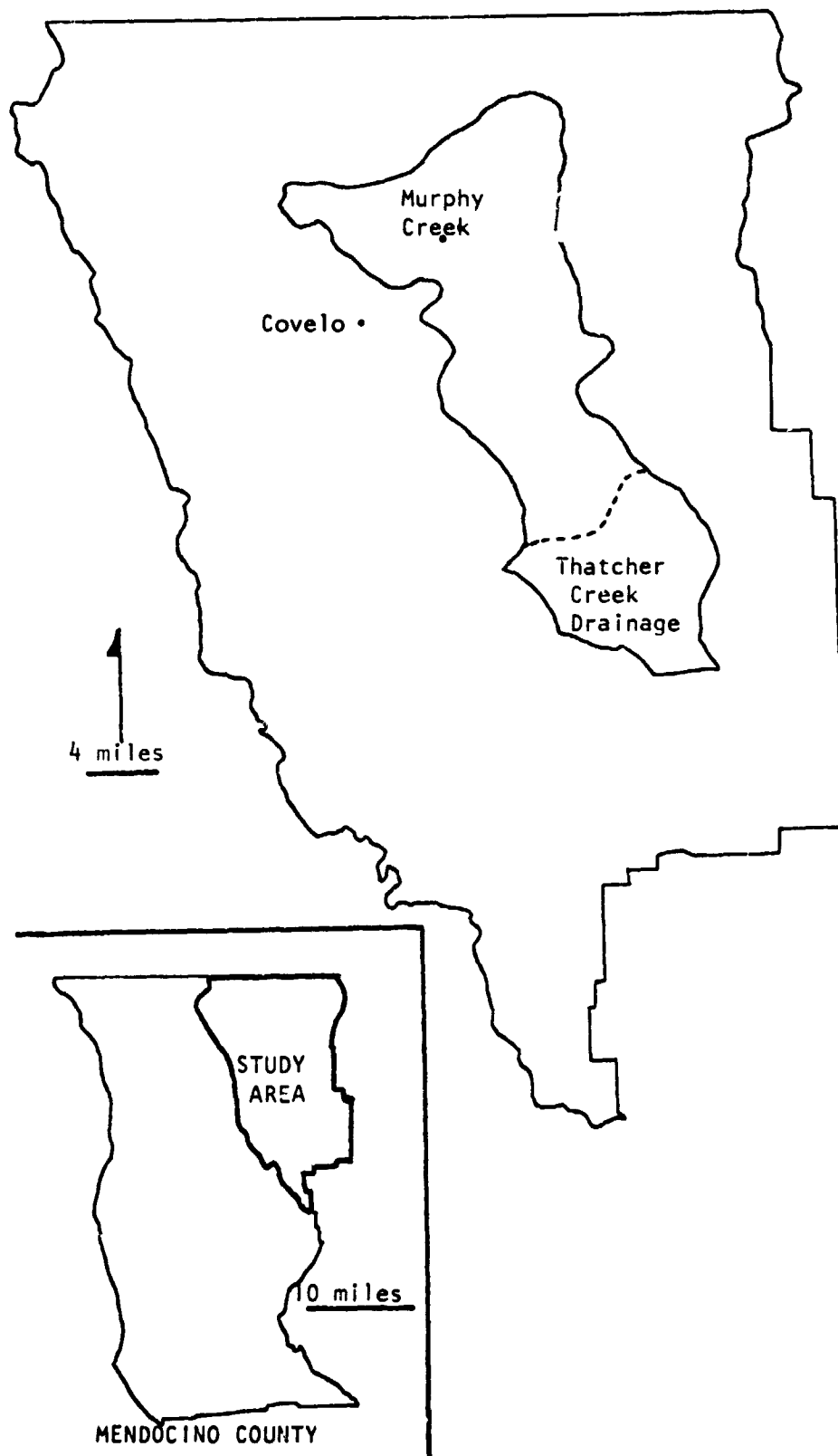


Figure 2. Location of the pilot study area and the expanded study area in northeastern Mendocino County, California. Located within the pilot study area are the Murphy Creek and Thatcher Creek drainages where range improvement and fuel modification work is being carried out by the Bureau of Indian Affairs and the U.S. Forest Service.

On 15 July 1977 the FMC convened in Covelo. Part of the meeting was devoted to an evaluation of the remote sensing data products that had been produced up to that time by RSRP personnel and ways in which those products might be used and added to. As a result of that meeting, the following three conclusions were reached:

1. The vegetation map with its geographic and property overlays (as previously prepared by personnel from RSRP and the FMC Mapping Unit) provided a valuable base from which to develop a basic fuel plan. The ten vegetation types appearing on that map, however, were those which were spectrally dissimilar, and not necessarily those which had different fuel characteristics. If possible, a subsequent vegetation classification should be made which would match more closely the final fuel types as defined by the California Department of Forestry (CDF) and the U.S. Forest Service (USFS).
2. The 80,000 acre Covelo study area was a good pilot area in that (1) it exhibited a good array of fuel types and associated fuel management problems, and (2) a desirably large number of agencies were involved in managing portions of the area, thereby permitting the area to serve as one in which to demonstrate the concept of Coordinated Resource Planning. It was too limited an area, however, to represent the complete range of fuel types occurring within the county. In particular, very little mature commercial conifer or recently logged timber was present. Therefore it was agreed that an expanded study area, centered somewhat around the original study area, should be selected such that these important additional fuel types would be included.
3. Although the soils overlay to the vegetation map provided valuable input for use in planning and implementing a management plan, two problems limited its usefulness: (1) The two sources of data for this overlay, namely, the Soil Conservation Service and the U.S. Forest Service, used two different mapping criteria with the result that the soils data could not be easily combined; and (2) the soils information from these sources was

too detailed to be easily implemented into a fuel management plan. Ideally, the only soils information needed in relation to this study would be a soils overlay giving general soil type, viz., coniferous forest soils, hardwood soils, and grassland soils, and the range of soil depths of each.

2.3 Objectives for Future Work

Based, in part, on the foregoing FMC evaluation of last year's remote sensing-derived products, the current study area has been expanded to include the entire northeastern quarter of Mendocino County (see Figure 2). This larger area includes large stands of commercial conifer and recently logged areas, the two most important vegetation types that were not widely represented in the smaller pilot area. In addition, this expanded area provides a far better representation of private landowners (the group whose involvement is especially desired under the Coordinated Resource Planning concept, as described in Appendix A of this report).

Landsat digital data covering the area will be classified into fuel types similar to those defined by the USFS in Table 1. The classification approach to be used will be the "mixed" procedure that was used to classify the pilot study area. With this procedure, an automatic clustering algorithm defines the spectral clusters which are used to train the maximum likelihood classifier.

The fuel types listed in Table 1 will have to be modified such that (1) those fuel types that can be discriminated through the use of Landsat data will be included and (2) type definitions will be employed that can be used by all user agencies for management actions within the study area.

The output products from Landsat classification will be overlaid with separate information sheets, pertaining respectively to soils, property, topography, and watershed attributes of each portion of the area. These products will be given to FMC personnel (and, through them, to the landowners and government agencies that are concerned with the area's resources and fuel hazard problems), to assist them in developing and implementing various management plans.

Table 1. U.S. Forest Service Fuel Types¹

<u>Fuel Type</u>	<u>Description</u>
1	Grass
2	Grass and Scattered Sage
3	Mature Timber - Little Chopping
4	Bear Clover
5	Open Manzanita - Patchy Brush
6	Timber - Medium Reproduction and Brush
7	Light to Medium Chamise - Southern California
8	Brush Mixtures with Sage
9	Medium Brush - In Cutover or Timber Brush
10	Mixed Douglas Fir - White Fir with Brush and Reproduction
11	Medium Brush and Oak - Southern California
12	Heavy Pure Manzanita, Chamise or Buck Brush
13	Heavy Mixed Brush
14	Heaviest Mixed Brush
15	Second Growth - Medium Poles
16	Slash in Cutovers
17	Woodland - Little Chopping

1) U.S. Forest Service, 1973. Region 5 Supplement No. 1 to the Fireline Handbook, FSH 5109.17, page 20.9.

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Personnel from the RSRP will continue to monitor field work that is carried out within the study area especially that directed primarily by the analysis of the remote sensing data.

Finally, RSRP's detailed remote sensing-based studies will continue in the Thatcher Creek drainage area, an area that was selected within the original pilot study area based on the analysis of the Landsat classification and the ancillary data. The objective of this intensive study is to develop in detail and then to implement a fuel modification plan based primarily on information acquired through the interpretation of small scale aerial photography but supplemented to a limited extent with field data. The intensive plan, like its more general predecessor, will continue to recommend areas of the Thatcher Creek drainage within which vegetation should be modified primarily through the removal of brush. Included in each recommendation will be an appraisal as to the best method for that modification, e.g., prescribed burning, mechanical removal, or hand removal of the brush.

2.4 Results to Date and Anticipated

2.4.1 Landsat Digital Processing

Landsat digital data were obtained for the expanded study area and data processing is proceeding. These data have been reformatted in order to be compatible with the RSRP minicomputer system, on which most of the processing is done, and with the Lawrence Berkeley Laboratory's (LBL) CDC 7600/6600 system, on which the major classification procedures are performed. The transformation of raw Landsat digital data into the major fuel classes is being accomplished using a "mixed" classification procedure which will be described briefly in the following paragraphs. A complete description of the procedure is given in Cosentino, et al., 1977.

The procedure calls for a sample of Landsat spectral data to be extracted from within the boundaries of the study area. With these data, mathematical models are developed which describe all vegetation and ground conditions within the study area. These models, or spectral clusters, are automatically defined through the use of an iterative algorithm in which the program operator establishes the maximum range of values acceptable to a given cluster, the allowable overlap (if any)

between clusters, and the minimum number of data points which constitute a cluster. The model for each cluster is composed of the spectral means and standard deviations for each Landsat band and the covariance between Landsat bands.

A key step in this classification procedure is the correlation of spectral clusters to given fuel types. In most cases, a given fuel class within an area will be composed of a number of spectral clusters. This is to be expected because the spectral reflectance that is recorded by Landsat for a given area is the result of a complex interaction of electromagnetic energy with the vegetation canopy and soil background. In addition, the spectral reflectance is influenced by geographical factors such as the steepness and aspect of slopes. For example, Fuel Type 1, Grass, could be composed of three statistically different spectral clusters depending on whether it was present on north or south slopes or ridge tops.

The spectral clusters are correlated to fuel types by comparing their spatial distributions to those of fuel types identified on aerial photos. This is often a time consuming process because every cluster must be first located on aerial photos and then their identities determined. In order for this step to be carried out successfully, there must be close interaction between the remote sensing specialist who manipulates the data and the fuel management expert who is familiar with the vegetation types in the area of interest.

After the spectral clusters have been combined into fuel types, the labelled models are input as training to a maximum likelihood classifier. This classification algorithm calculates the statistics for each Landsat pixel and assigns it to the fuel type model to which it is statistically most similar. After this point-by-point classification has been completed, the fuel type statistics are summarized and a fuel type map is written on magnetic tape for transformation to hard copy photographic products.

2.4.2 Monitoring Field Activities

Throughout the past summer, personnel from the RSRP have been monitoring the range improvement program being carried out on Bureau of Indian Affairs (BIA) land within the pilot study area. The sites in which this program is being implemented were selected, in part, through the manual interpretation of small scale aerial photography.

At the beginning of 1977, the BIA was given funding under the Comprehensive Employment Act for immediate range and forest land improvement. At that time, there were no vegetation maps available from which to derive recommendations to where on BIA land these actions could best be taken. Small scale color infrared transparencies from July 1972, however, were available from NASA. These photos were interpreted by personnel from the RSRP, BIA, and Mendocino County Farm Advisors Office. From these interpretation results, areas within the Murphy Creek Drainage were selected for carrying out concentrated ground efforts.

The objective of the vegetation modification in the Murphy Creek Drainage is primarily for range improvement. Secondary objectives include the reduction of fire hazard and the production of firewood. Much of the grassland in the drainage has been invaded by oak and brush. This has greatly reduced the carrying capacity of the range and the amount of available water for livestock. In addition, the presence of these highly volatile woody fuels negates the usefulness of these grasslands as natural fuel breaks. These conditions are easily interpreted from small scale color infrared stereo transparencies. An example of the thinning operations that are being carried out in Murphy Creek (see Figure 3a) is shown in Figure 4.

This thinning operation is a good example of one of the most basic applications of remote sensing data to wildland management. Often, as in this case, federal monies are made available on short notice and must be spent in specific time periods. If these funds are to be spent for wildland improvements, areas to be improved must be selected and prioritized based on expected success and available funding. Frequently these areas can be selected only through the interpretation of historic remote sensing data because of limitations of personnel and monetary resources and/or inaccessibility of the topography. It must be emphasized that if wildland management actions are applied either improperly or in a haphazard manner, the result is likely to include irreversible ecological damage and a waste of financial resources.

2.4.3 Development of a Fuel Management Plan for the Thatcher Creek Drainage

As previously indicated, it was a result of an examination of the Landsat classification of the pilot study area by members of the FMC that the Thatcher Creek drainage was selected as a test area in which to develop a detailed fuel management plan based on remote sensing and other data. This 24,000 acre watershed was selected for one primary reason: the vegetation complex within the drainage varies from valuable grass and timber lands in the east to dense stands of brush lands in the west. An aggressive management plan in the western half, therefore, is needed to protect valuable resources in the east. A major part of this western portion is covered by an unbroken homogeneous stand of decadent chamise. Modification of this vegetation component to a brush-grassland mosaic would have the multiple benefits of reducing fuel hazards, improving wildlife habitat, and increasing soil stability.

The Thatcher Creek drainage, as photographed on 2 July 1972 from the RB-57 aircraft, is outlined in Figure 5a, and the vegetation, as mapped from this photo, is given in Figure 5b. This photo and the map clearly illustrate the particular fire hazard described above. Most of the western third of the drainage is covered with decadent stands of chamise. If an ignition occurred at the western edge (Area A), the resulting fire would probably gather momentum, jump the preliminary fire breaks that have been constructed by the USFS (dashed lines in Area B), and consume valuable timber resources (Area C). An example of what can be expected if a wildfire is started in this drainage can be seen on the slopes surrounding Area D. This area had a similar vegetative cover as seen at Area A prior to the 1968 Horse Pasture Ridge Fire which destroyed all the vegetation on this slope.

It must be emphasized that, even prior to RSRP's involvement with the Thatcher Creek drainage, not only had a somewhat general fuel management plan already been developed for this area but also major aspects of that plan already were being implemented. This is evident by examining Figure 5a on which the fuel breaks which have been constructed since the photos were acquired have been annotated. This fact

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was recognized as constituting an additional favorable factor in selecting the Thatcher Creek drainage. Had some other area been selected, many months or even years might have elapsed before appropriations could be made and actions taken. Not so in the Thatcher Creek drainage. The consideration there was whether a remote sensing based analysis could be made quickly enough to permit its consideration in each of several phases of the on-going brush manipulation project. As indicated by several of the photographic illustrations appearing in the remainder of this chapter (Figures 6-19), our remote sensing efforts did, indeed, prove to be timely and to affect decisions as to what should be done next in this on-going project. This refreshing element of urgency has proved to be one of the strongest aspects of our remote sensing involvement in the Thatcher Creek drainage, and is likely to continue to be both there and in much of our enlarged test area, viz., the northeast quarter of Mendocino County. Lest there be any mistake about this element of urgency (in saving the valuable resources of this area from destruction by a major holocaust), details need to be given here with respect to a naturally occurring wildfire that broke out in the Thatcher Creek drainage, even as our study was proceeding. It is especially instructive to compare the damage actually done by that fire with that which might have occurred in the absence of measures that had already been taken in the on-going program.

This 155 acre fire began (apparently from natural causes) at approximately 4 pm on September 4, 1977. The net damage done by the fire was minimal and perhaps was more than offset by certain benefits derived from it (e.g. the improvement of wildlife habitat by opening up impenetrably dense stands of brush; the reduction of fuel and the consequent reduction in fire hazard in this critically located area).

A far greater degree of damage almost certainly would have resulted, however, if (a) the fire had started farther down the slope (see Figure 13); or (b) it had started earlier in the day. In fact experts of the USFS, working with their counterparts in the CDF have officially estimated that, had the above unfavorable combination of circumstances prevailed, the damage might have been in excess of \$15 million. This figure includes (a) the value of the old growth and young growth timber stands that would

have been destroyed; (b) the damage that would have resulted from soil erosion, including damage to fisheries for a very extensive distance downstream as a result of siltation; and (c) the costs of various fire suppression activities and post-fire rehabilitation measures. Furthermore, even with the fire having started when and where it did, this very large economic loss might have occurred, if preliminary firebreaks had not already been constructed.

With each working day, however, there is a significant decrease in the likelihood that, even in the "worst case" of fire outbreak, severe damage and economic loss would result. As each new segment of firebreak is constructed or improved upon (see for example Figures 9 and 10), and as each additional patch within an extensive brushfield of the Thatcher Creek drainage is either mechanically cleared of brush or subjected to controlled burning, (see for example Figures 14 and 19), the fire hazard throughout this entire area is substantially reduced. Since remote sensing already has been used in the planning and execution of such measures in the Thatcher Creek drainage, and will be used even more extensively in the future, it is in the light of potential loss figures such as those quoted above that one can begin to appreciate the great potential benefit of remote sensing-derived information. Furthermore, just as we are exploiting the usefulness of remote sensing in this particular area, so it should prove useful also in the hundreds of other "Thatcher Creek drainages" throughout California and elsewhere.

Before concluding our consideration of potential damage that can be done by fire in California's brushfields, we must recognize that a large dam and reservoir system often is constructed downstream from such a brush covered watershed. (In fact it has long been proposed that a 300-foot-high dam be constructed downstream from this very drainage.) In the Thatcher Creek drainage, as in most of these other areas, there is every likelihood that a major fire would lead to soil erosion that would so completely fill any downstream reservoir with silt as to make that reservoir useless for its intended purposes. In such instances it would be only realistic to add costs that were entailed in constructing the reservoir or system of reservoirs (often totalling several hundred million dollars) to the previously mentioned damage estimate, in dollars, that can result from a major

brushfield fire. Furthermore, the silting in of a reservoir site may destroy forever the potential benefits derivable from reservoir construction in the area including (a) the increased availability of impounded water for irrigation and for domestic and industrial use; (b) the increased opportunity to enjoy fishing, swimming, water skiing, boating, and other water sports within the reservoir area itself; and (c) the decreased likelihood that highly damaging floods will occur downstream from the reservoir.

On December 16, 1977, representatives from the major land owners in the Thatcher Creek drainage with technical assistance from the RSRP and Mendocino County Farm Advisors office will begin developing a Coordinated Resources Plan for the drainage. This plan will define management objectives plus data requirements. It is needed to formalize the responsibilities of the plan as defined in earlier meetings. A primary objective of the plan will be to reduce still further the fuel hazard within the drainage in order to prevent conflagrations which might destroy valuable timber and watershed resources. Secondary results will include improving wildlife habitat, range forage, and water quality and quantity.

Major fuel modification within the Thatcher Creek drainage cannot be expected until at least a year after the Coordinated Resources Plan has been completed. Preparatory actions, however, in the form of widening the fire lines along Horse Pasture and Hayshed Ridges (Points E, Figure 5a) into fuel breaks may begin next fall if manpower and equipment are available. Such fuel breaks would be required if any subsequent fuel modification action in the drainage would use prescribed burning as the management tool.

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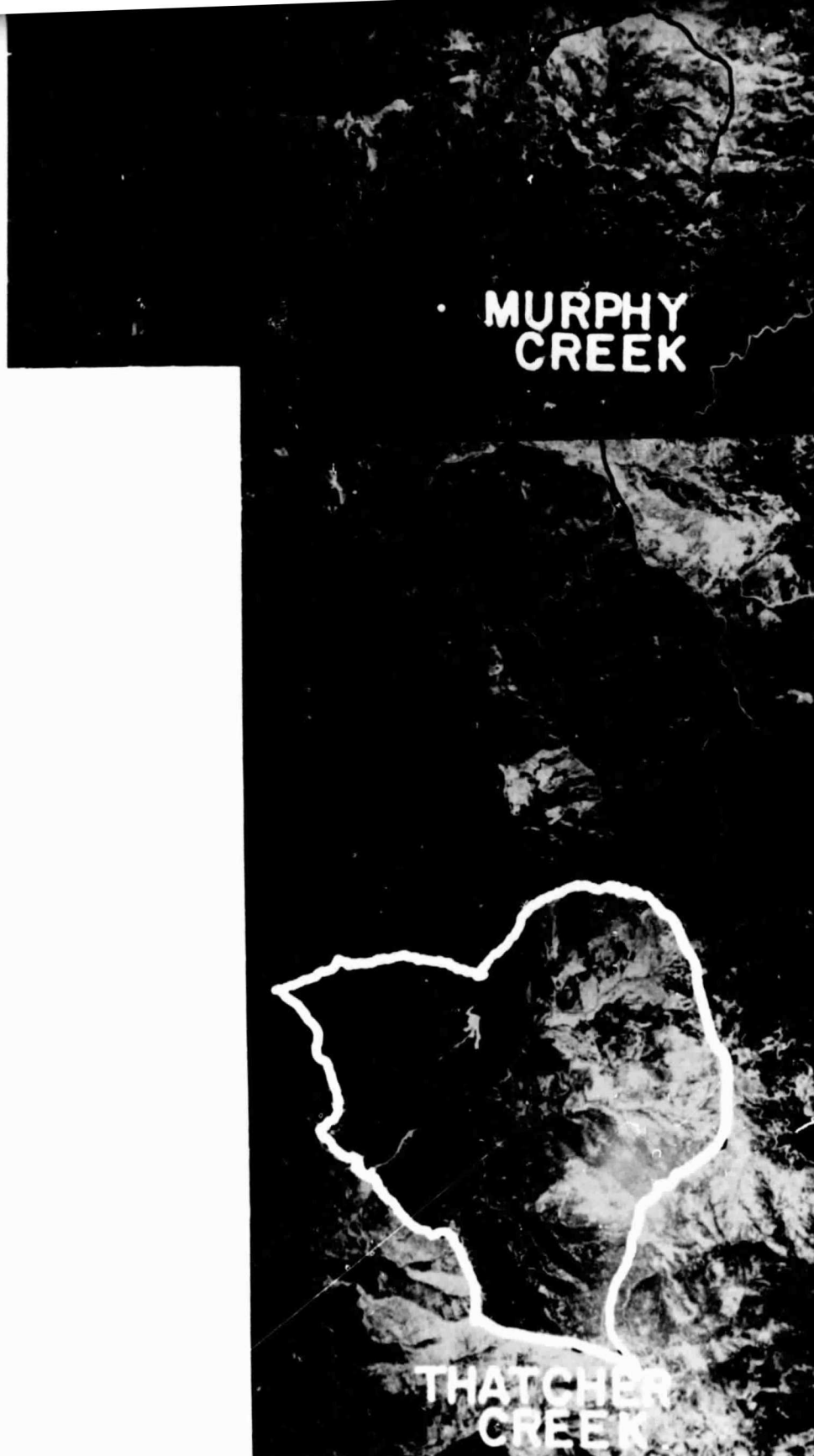
Cosentino, Michael J., et al., 1977. Fuel Mapping in Relation to Management of Brushlands and Timberlands in Mendocino County, California. Chapter 2 in Application of Remote Sensing Data to Selected Problems in the State of California. Annual Progress Report for NASA Grant #NSG 7220. Robert N. Colwell, principal investigator.

ACKNOWLEDGEMENTS

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Our thanks also are extended to representatives of both the U.S. Forest Service and the California Department of Forestry in Covelo for their willingness to cooperate with us fully in our efforts to maximize the usefulness to them (in their capacity as resource managers) of our remote sensing-derived information. Their careful analysis of the photographs and the captions that appear in this chapter has done much to ensure that these materials would accurately illustrate both the uses and the limitations of remote sensing in relation to their various resource management objectives.

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Figure 3a. A mosaic of the 80,000 acre pilot study area east of Covelo, California, made from small scale color infrared transparencies acquired with the NASA RB-57 aircraft. The Murphy Creek and Thatcher Creek drainages are annotated where fuel modification actions are being implemented by the Bureau of Indian Affairs and U.S. Forest Service. See text for additional details.

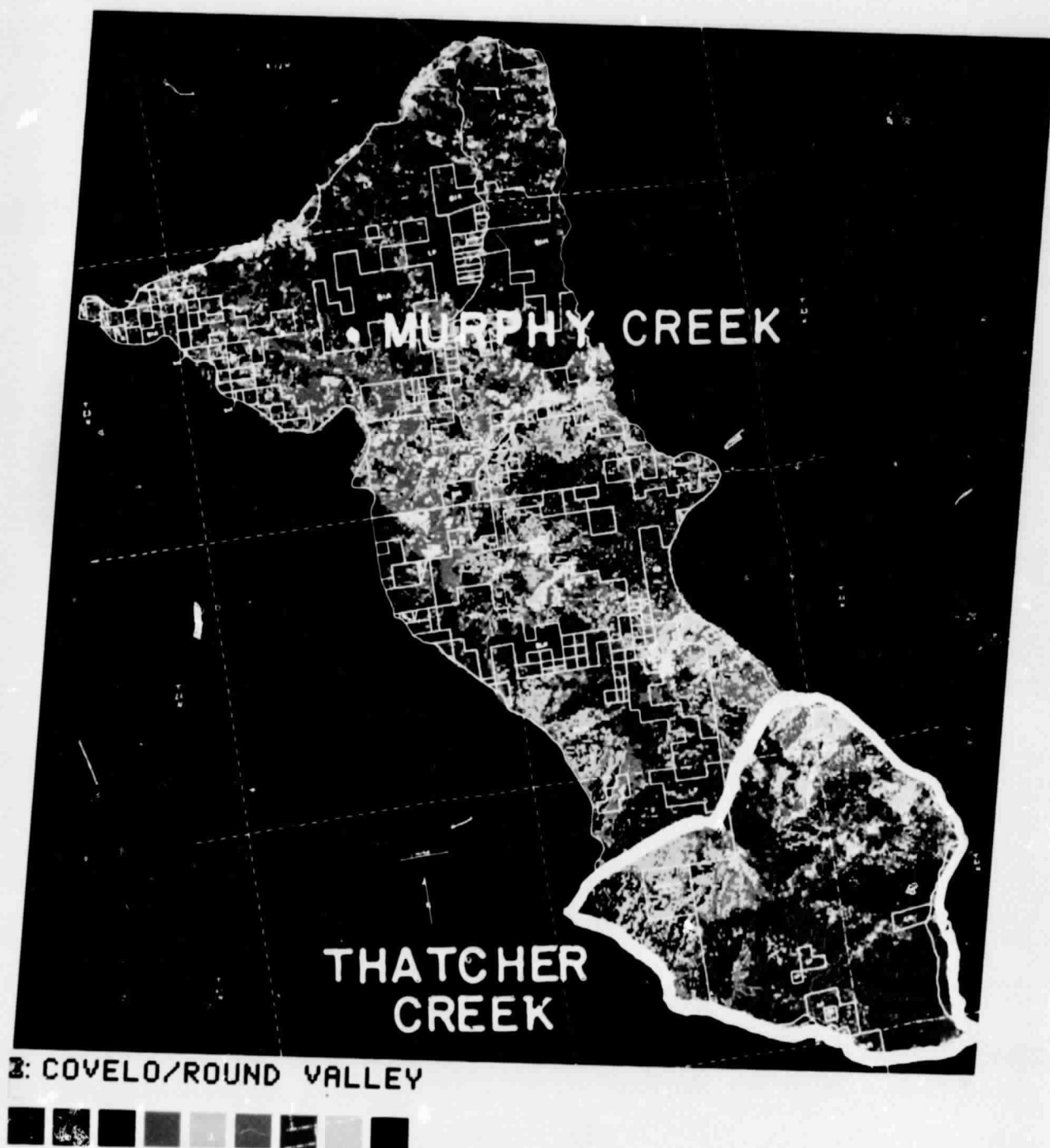


Figure 3b. The pilot study area as classified from Landsat digital data. The transportation network plus property boundaries have been superimposed on the color coded classification. The ten color classes from left to right represent respectively: 1. hardwood-conifer-mixed brush; 2. hardwood-conifer-barren; 3. hardwood-mixed brush-barren; 4. hardwood-grass-mixed brush; 5. grass; 6. grass-hardwood-brush; 7. grass-barren; 8. chamise; 9. conifer-barren-hardwood; and 10. barren-grass-mixed brush.



Figure 4. Thinning operations being conducted by the Bureau of Indian Affairs in the Murphy Creek drainage. This area, selected in part from the interpretation of small scale color infrared transparencies, is located in Figure 3a.

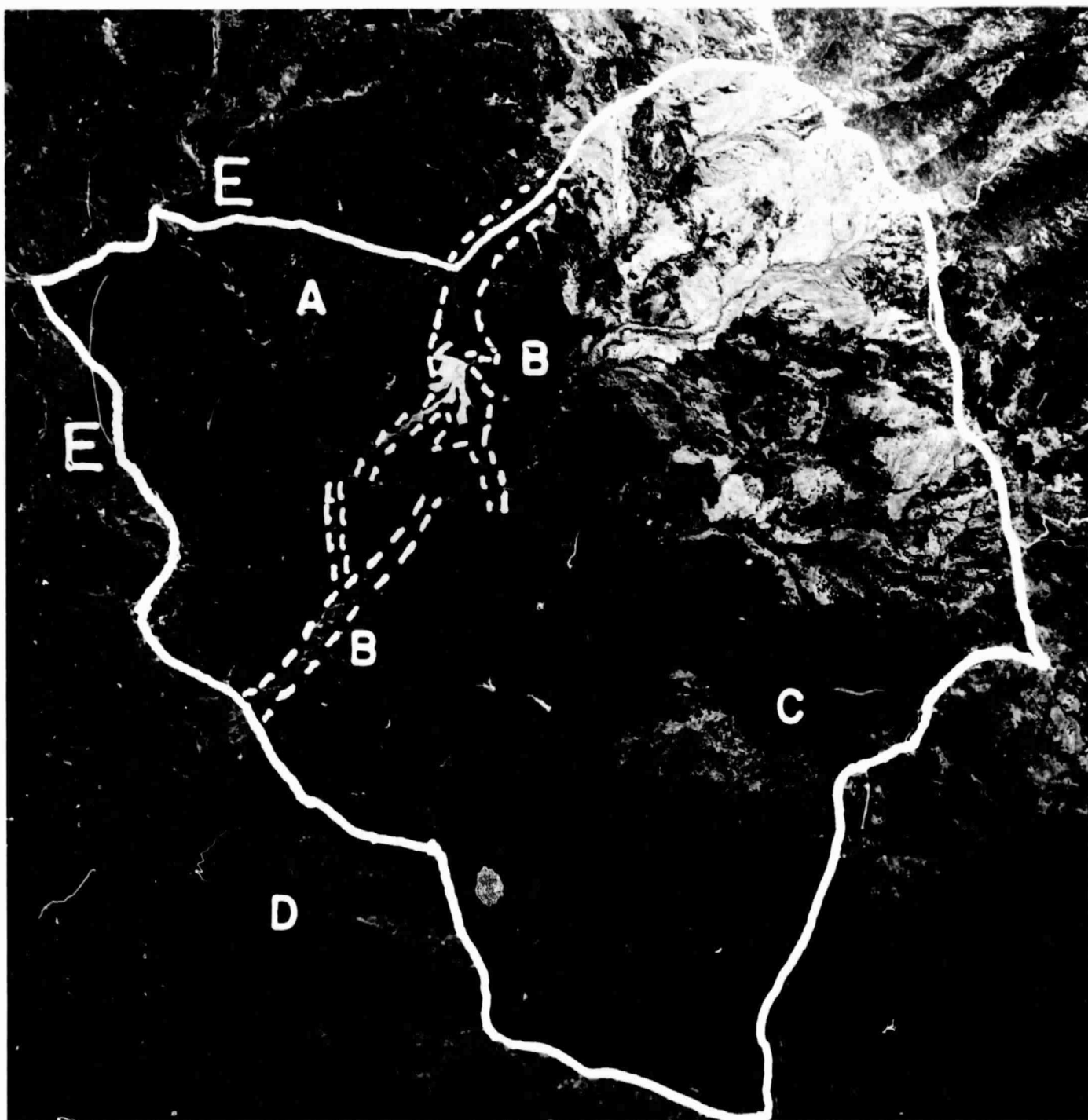


Figure 5a. The Thatcher Creek drainage as photographed from the RB-57 aircraft on 2 July 1972. "A" is an area of heavy chamise vegetation. "B" is an area where U.S. Forest Service fuel lines and breaks are being constructed. The dashed lines are fire lines which have been constructed subsequent to the photo acquisition. "C" is an area of commercial conifers. Area "D" is the 1968 Horse Pasture Ridge burn. Points "E" are two ridges where fuel breaks may be constructed in fall 1978. This 24,000 acre area represents only 15% of the total area covered on the original 1:120,000 scale 9x9 inch photo.

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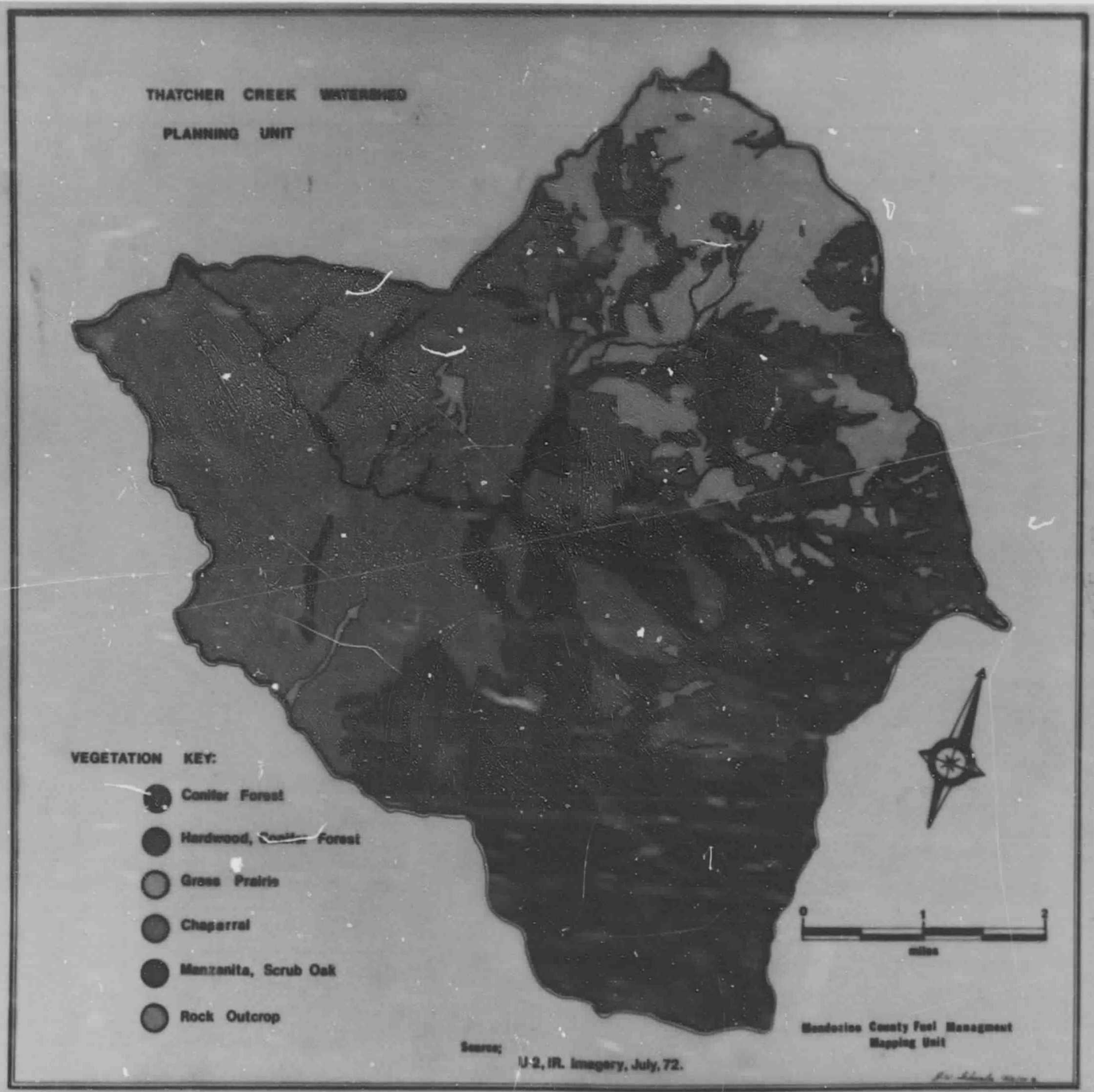


Figure 5b. The vegetation in the Thatcher Creek drainage as mapped from the photo given in Figure 5a. This map was drawn by personnel from the Mapping Unit of the Mendocino County Fuel Management Committee, using NASA photography including that shown in Figure 5a.

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Figure 6. Stereo triplet of Round Valley area in Mendocino County made from Ektachrome photos that were taken from an altitude of approximately 1500 feet above the terrain on 2 November 1977. The town of Covelo is in the top of the photo, near the center of Round Valley. In the upper left, partly obscured by clouds, is the Thatcher Creek drainage in which remote sensing-based studies are being made to better improve brushfield manipulation, timber harvesting practices, and the treatment of wildlife habitats. Federal agencies owning land and/or interested in resource management in the area shown here include Bureau of Land Management, Bureau of Indian Affairs, Forest Service, Bureau of Outdoor Recreation and the Fish and Wildlife Service. State agencies include the Department of Forestry, the Department of Fish and Game, and the Department of Water Resources within the California Water Resources Agency. County agencies include the Mendocino County Board of Supervisors, the County Farm Advisors and the County Brushfield Committee. Figures 7-19 provide photographic illustration of remote sensing-aided work which these various agencies are undertaking within the area shown here with the aid of remote sensing expertise provided by personnel of the Remote Sensing Research Program of the University of California.

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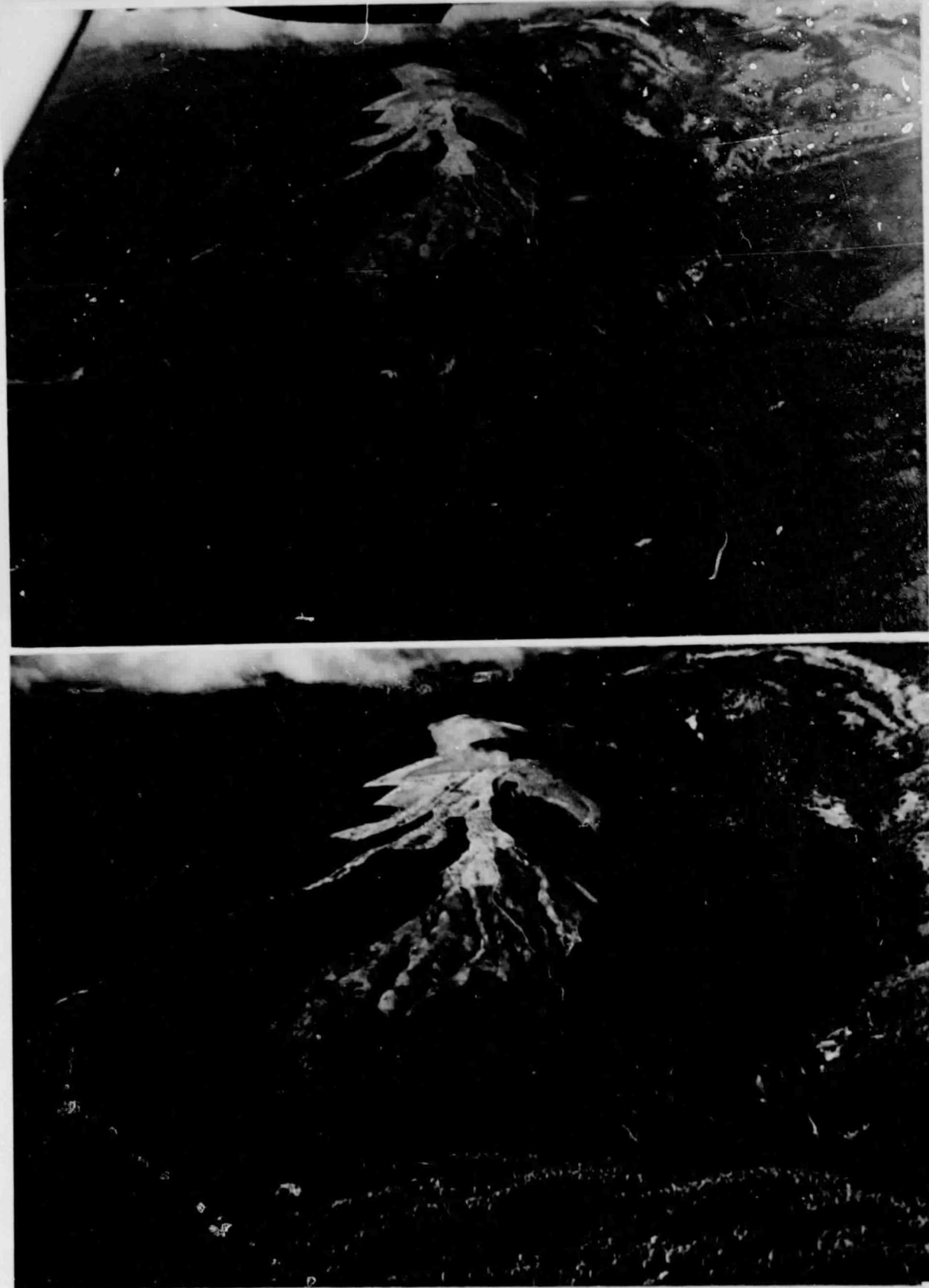


Figure 7. Aerial photos of the Thatcher Creek drainage taken with Ektachrome (top) and infrared color films on 2 November 1977. Brushfield manipulations aimed at fire hazard reduction and wildlife habitat improvement are apparent in the center of these photos. In the lower right quarter of each photo the edge of a valuable timber stand is barely seen. Similarly in the upper right corner, the edge of an extensive oak-grassland area can be seen within which sites are being selected for oak mapping studies and the possible transplanting of wild turkeys.

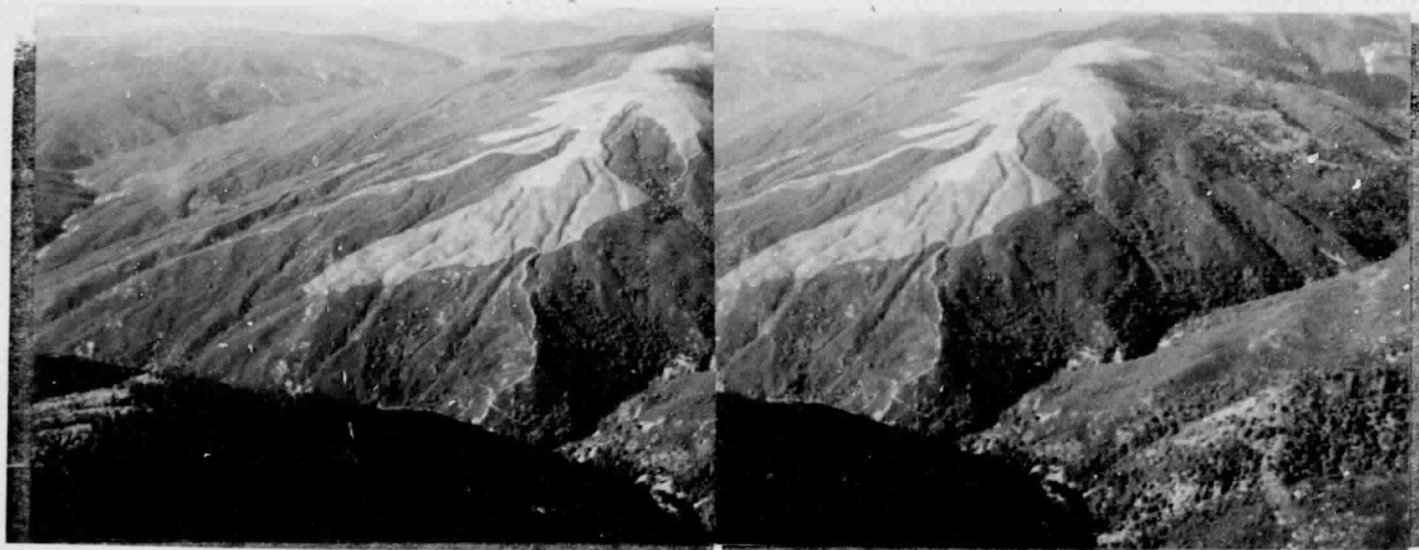


Figure 8. From this stereo pair of aerial photos of the Thatcher Creek drainage, one can appreciate the steepness of slopes and the three-dimensional configuration of the terrain far better than would otherwise be possible. Note that, on the far side of Thatcher Creek, it has been possible, in clearing the brush, to use mechanized equipment (See Fig 10) but only where slopes were not too steep. Mechanized equipment also can be used for drill seeding such areas after brush removal in order to establish a suitable cover of rye grass in admixture with the sprouting brush, as shown in Figure 9.

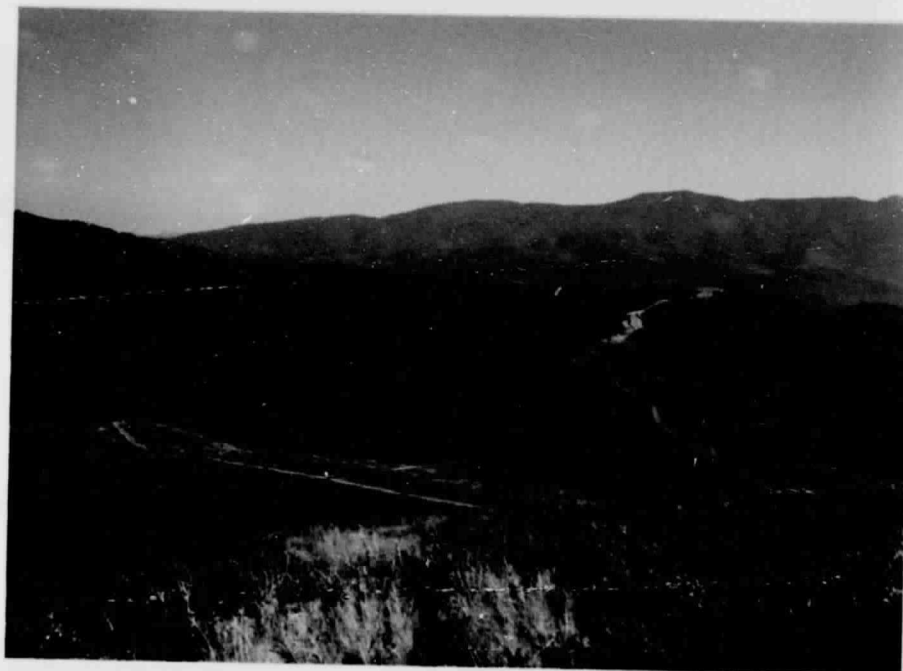


Figure 9. Aerial and terrestrial photos on which can be seen important additional details with respect to brushfield clearing and seeding activities within the Thatcher Creek drainage. Remote sensing is proving valuable in this area not only for the planning of such activities but for the subsequent monitoring of the impact which they have had on the landscape. Although the entire area appearing in the bottom photo was only recently cleared, brush already is sprouting vigorously in most of it. The light yellow color of the grass at this time of year (Fall 1977) reveals the drill seeding pattern on this moderately steep slope.

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Figure 10. With the aid of mechanized equipment a firebreak is being constructed here. Note that the brush has been bulldozed into piles for burning. This slope is directly across Thatcher Creek from the one appearing in Figure 7. The piles of brush shown in these August 1977 photos can be seen burning in the November 1977 aerial photo appearing at the bottom of Figure 11.



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Figure 11. The firebreak shown in Figure 10 can be seen at "A" on each of these three photos. Note in the bottom photo (taken November 2, 1977) that brush piles can be seen burning.



Figure 12. Shown here are two aerial photos of an area in the Thatcher Creek drainage within which, on August 10, 1977, a wildfire started that might have burned the entire Thatcher Creek watershed and more. Its location with respect to the previously illustrated areas can be deduced from the top photo of this Figure which was taken on November 2, 1977. For example in the top left of that photo is the brushfield clearing that appears in Figure 7 and across from it, in the top right, is the firebreak seen in Figure 11. See, also, Figure 13.

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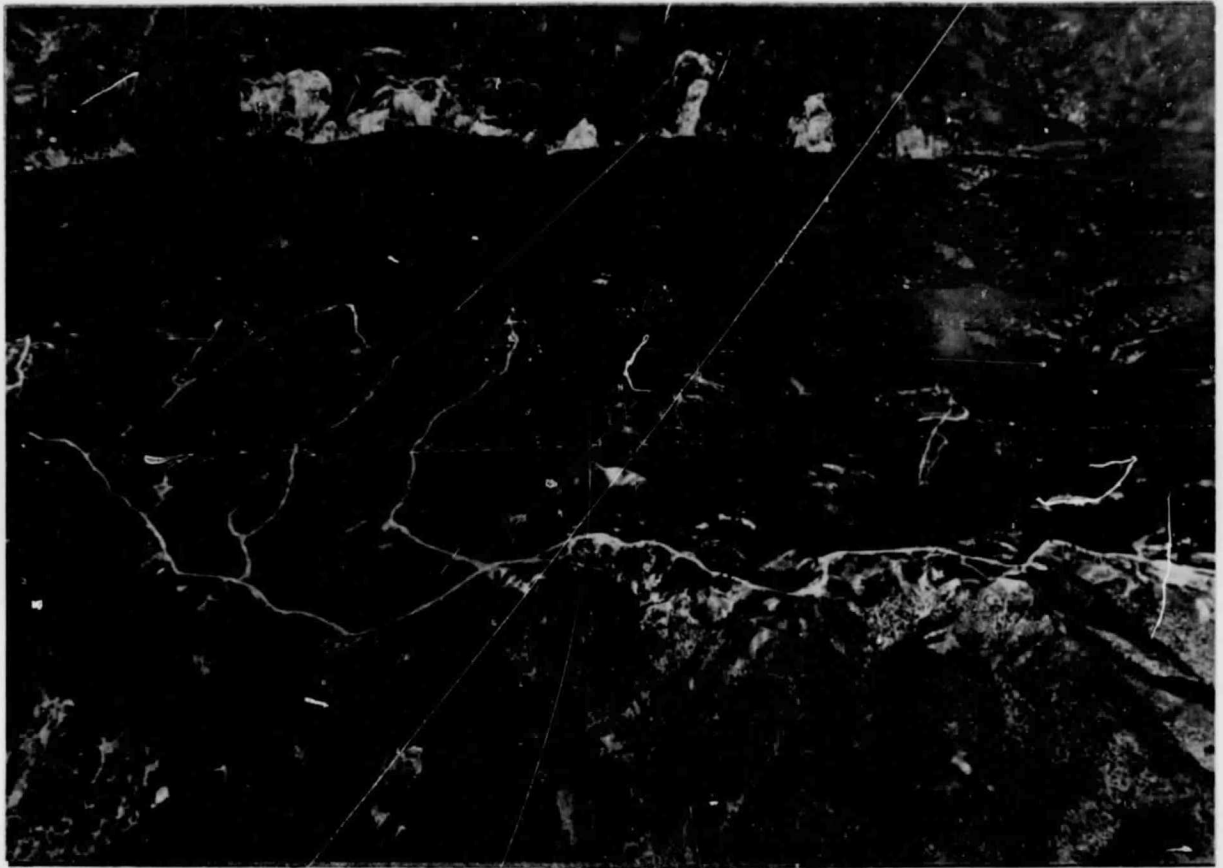


Figure 13. Another November 1977 aerial photo of the area shown in Figure 12 in which a 155-acre wildfire occurred on August 10, 1977. That fire very nearly jumped the ridge at several spots appearing in the lower left corner of this photo. Accordingly, plans are being made to widen this ridgetop road and firebreak during the coming year, especially in those portions of it where remote sensing indicates the need is greatest (i.e. where vegetation is the densest and slopes are the steepest). Thatcher Creek drains from right to left through the area shown in the top third of this photo. The light toned areas along its far bank are where "slip-outs" have occurred due to unstable soils on steep slopes. The resulting siltation can endanger the survival of steel-head trout which are an important fisheries resource in the area. As shown in Figure 8, it is important to leave a "buffer strip" of vegetation above such "slip-out susceptible" areas. Remote sensing is being used to locate these high hazard areas and to delineate the boundaries of the necessary buffer zones.



Figure 14. Parked on top the ridge at the end of a long day is this important brush-removing device, a D-7 caterpillar tractor with an attachment known as a "brush rake." At the time when this picture was taken in September 1977, it had just finished tieing together the fire breaks on the north and south slopes of the Thatcher Creek drainage. Preliminary plans for this activity and some firebreak construction already were under way at the time when the "Mendocino County Remote Sensing Project" was initiated. Those in charge of the actual brushfield manipulation work have stated, however, that since then plans and activities have been substantially modified and improved because of the remote sensing-derived information.

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Figure 15. (Left): With the aid of mechanized equipment, an herbicide spray has been applied to trees and shrubs along the edge of one of the Thatcher Creek brushfield clearings to discourage brush invasion of the cleared area. (Right): Shown here is a road that was built along the ridge top of the Thatcher Creek drainage several years ago. Even on aerial photos it was possible to see the invading brush which is rapidly reducing the effectiveness of the road, both as a firebreak and as a route of access in the event that a fire should occur in the area. Activities designed to improve roads and firebreaks in the Thatcher Creek drainage appear in Figures 10 and 11.



Figure 16. Approximately one third of the Thatcher Creek drainage area is covered with valuable stands of coniferous timber including those seen here. At the time when the University's RSRP personnel took this aerial photo of the area on November 2, 1977, the first fall rainstorm already had occurred. The rains had sufficiently reduced the fire hazard so that slash piles resulting from the previous summer's logging operations could be safely burned (Note the numerous smoke plumes). Under the "Mendocino Project" investigations are under way in this area to determine the potential usefulness of remote sensing in relation to the planning, implementing and monitoring of timber harvesting and timber management activities.



Figure 17. An additional third of the Thatcher Creek drainage area is occupied by an oak-grassland type, as shown in this aerial photo taken by the University's RSRP personnel on November 2, 1977. On that flight an expert on bird habitat (an employee of the California Department of Fish and Game) was aboard to help determine the extent to which remote sensing, combined with direct visual observation, could facilitate the location of areas in which wild turkeys could be successfully transplanted.



Figure 18. All three vegetation types encountered in the Thatcher Creek drainage area are shown in this one view, together with certain intermediate or transition zones. Brush stands can be seen across Thatcher Creek in the extreme upper left corner of this photo and also in much of the bottom right quarter of the photo. Timber stands fringe the left and bottom edges of the photo. The oak-grassland type occupies the lightest toned areas here and in Figure 17.

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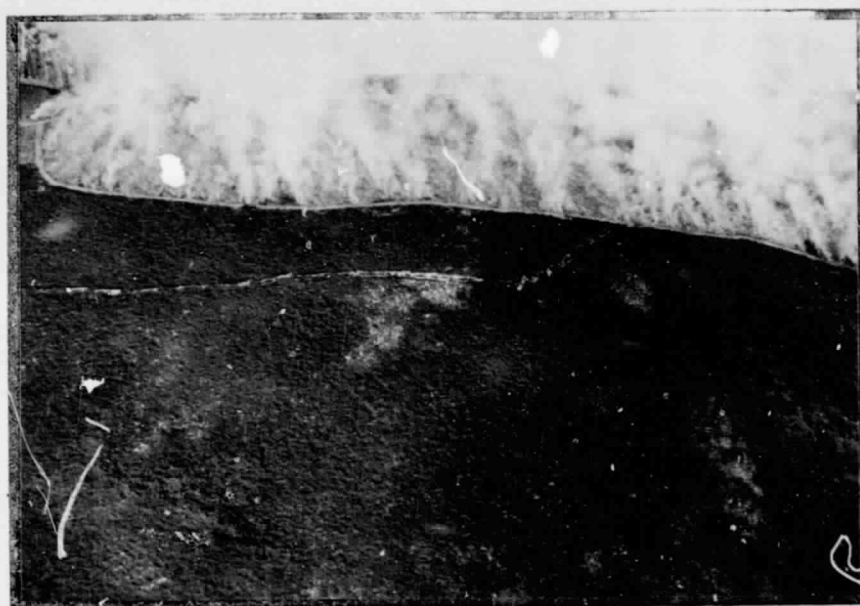


Figure 19. An oblique aerial photo of a prescribed burn being carried in a dense field of chamise in December 1976 by personnel of the U.S. Forest Service. This area lies within the Thatcher Creek drainage of the pilot study area in Mendocino County.

CHAPTER 3

CENTRAL CALIFORNIA STUDIES

Co-Principal Investigator: John E. Estes

PART I

Kern County Watershed Runoff Study

Project Manager: Robert R. Sasso

Contributors: Fred C. Mertz, Earl Hajic, Brenda Bowman

PART II

Fuel Moisture Content Estimation

Project Manager: Susan G. Atwater

Contributors: Michael J. Cosentino

PART III

Cotton Mapping From Landsat Imagery

Project Manager: Tara L. Torburn

Contributors: Larry R. Tinney

Geography Remote Sensing Unit

Santa Barbara Campus

University of California

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CHAPTER 3

PREFACE

The following three reports, emanating from the Santa Barbara Campus, University of California, are integrated under the title "Application of Remote Sensing to Selected Problems Within the State of California" sponsored through a grant from the NASA Office of University Affairs to the Space Sciences Laboratory.

The first report deals with the prediction of watershed runoff in relation to water storage and flood control under the mandated jurisdiction of the Kern County Water Agency. This study has progressed from the feasibility stage to the production of a specific product using NASA data and remote sensing technology which meets the user agency's needs in a cost effective and timely manner. The remaining items report the progress to date on two small feasibility studies concerning live fuel moisture content estimation (in conjunction with the Forest Service) and cotton mapping (in conjunction with the California Department of Food and Agriculture). These initial studies, if successful, will also be expanded to operationally test and eventually transfer remote sensing technology, documented at the university, to the state agencies involved.

CHAPTER 3

PART I

KERN COUNTY WATERSHED RUNOFF STUDY

Co-Principal Investigator: John E. Estes

Project Manager: Robert R. Sasso

Contributors: Fred C. Mertz, Earl Hajic, Brenda Bowman

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KERN COUNTY WATERSHED RUNOFF FEASIBILITY STUDY

INTRODUCTION

The Geography Remote Sensing Unit (GRSU), University of California, Santa Barbara, is currently conducting a preliminary research project in the Lake Isabella region, Kern County, California (Figure 1) which interfaces with the Kern County Water Agency (KCWA). The purpose of this study is to demonstrate the feasibility of acquiring vegetation cover information for input to watershed runoff prediction procedures used by KCWA. As part of their charter from the Kern County Board of Supervisors, KCWA is charged with specific flood control responsibilities. KCWA is to develop storm runoff predictions for all watersheds in Kern County in order to:

- Delineate flood plain boundaries which affect building standards for commercial and residential structures;
- Establish building standards for specialized flood control facilities such as dams, debris basins, spreading ponds, etc.; and
- Provide base-line data for flood insurance.

Initially, GRSU personnel have been working with KCWA to demonstrate the feasibility of employing both Landsat digital as well as aerial photography data to generate surface cover (primarily vegetation) information for input into the Agency's watershed runoff predictions.

KCWA currently uses the runoff prediction procedure developed by the United States Department of Agriculture's Soil Conservation Service (SCS). In this procedure runoff Curve Numbers (CN) are based upon the soil-cover complex present in an area, and are the major drivers of the SCS runoff

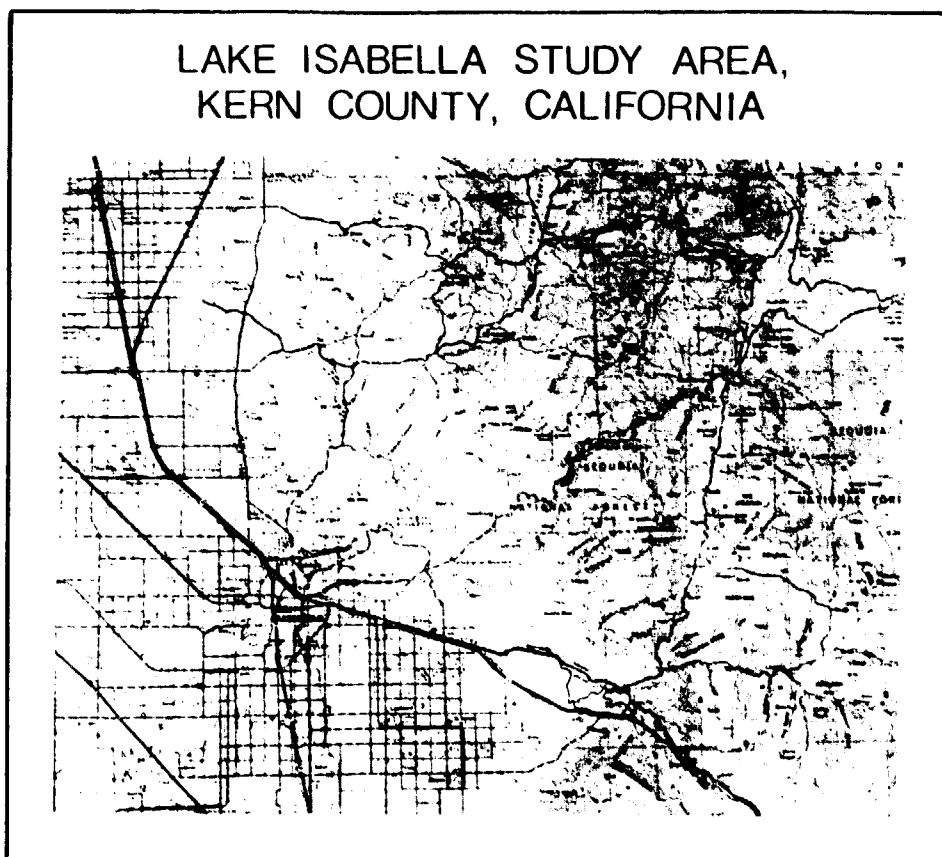


FIGURE 1. Lake Isabella is in the upper right, while Bakersfield, the County seat of Kern County, is at the lower left.

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equation. Appendix A contains an example of the type and level of detail (especially vegetation) required for the Southern California coastal plains and mountains in order to successfully implement the model. The SCS runoff equation is:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where: Q = runoff in inches
P = rainfall per storm
S = water storage factor equal to $(1000/CN - 10)$ where
CN = function of soil type, soil moisture, vegetation cover and density

The current method of generating vegetation data is by extensive terrestrial field survey techniques. Land use information, which includes data on vegetation cover, is derived by windshield survey as are data concerning hydrology. Current procedures for data acquisition are both time consuming and expensive as KCWA is mandated to provide watershed runoff predictions for over 2 million acres of mountainous watershed in Kern County. Consequently, the problem of collecting land cover data is of significant magnitude. Since vegetation cover is a major driver of the SCS runoff prediction equation, the data generated by remote sensing will impact directly upon the speed and accuracy with which curve numbers for given watersheds can be generated for use by KCWA.

TEST SITE BACKGROUND

Kern County is situated at the southern end of the Great Central Valley of California. Kings and Tulare Counties border Kern on the north and Inyo County to the northeast; San Bernardino County extends along the entire eastern boundary. On the west and south, Kern County

is bordered by San Luis Obispo, Santa Barbara, Ventura and Los Angeles Counties. The Lake Isabella test site lies in the southern extension of the Sierra Nevada mountains. Lake Isabella itself is at approximately 2000 feet elevation at the confluence of the north and south forks of the Kern River. The Kern and most other smaller streams in this area flow toward the southern portion of the San Joaquin Valley. The Kern, however, is the only major river in Kern County. It has an annual yield of approximately 615,000 acre feet per year. Complete and extensive use is made of the surface flow of the Kern mainly for agricultural purposes. Additional water has been supplied to Kern County by the Central Valley Project since 1959 and from the California Aqueduct since 1969. Even with increasing amounts of imported water, the Kern River surface flow (i.e. runoff) remains an important parameter in the water supply/demand picture for Kern County.

The San Joaquin Valley floor region of Kern County is characterized by extensive and intensive mechanized agriculture. Kern County is the second leading agricultural county in the United States in terms of agricultural dollar value. Sufficient water is not yet available for full agricultural development with only about half the potentially arable land in the county being cropped. Groundwater has accumulated in the Southern San Joaquin groundwater basin, over geologic time, in large volume. This groundwater supply is typically located within an economic pumping lift from the surface. At present, Kern County agriculture consumes approximately two million acre feet annually from this groundwater basin. This pumpage results in an overdraft to the extent of 700,000 to 800,000 acre-feet per year. If this overdraft continues,

the economics of pumping this underground water for agriculture usage will become critical. This reinforces the importance of maximizing the potential of the Kern River water supply.

TASKS PERFORMED SINCE LAST REPORT (MAY 1977)

Computer generated vegetation maps of the Isabella test region have been evaluated by GRSU and the user agency (KCWA). The resulting computer aided vegetation mapping procedures used by GRSU proved to be amenable to KCWA needs. Kern County Water Agency, therefore, has authorized payment to GRSU of ten thousand dollars for the completion of the computer aided vegetation classification of some 10,400 km² of mountainous watershed in Kern County. In addition to the \$10K hard money, an additional \$1000 in KCWA personnel time was agreed upon.

During this latter phase of research, the Geography Remote Sensing Unit will provide Kern County with computer generated vegetation maps of the study area. In most cases these maps will be 1:24,000 scale and correspond to the existing USGS topographic quadrangles. Kern County Water Agency may then use the vegetation information for input to the Soil Conservation Service's watershed runoff equation. Runoff curve numbers for Kern County watersheds then may be ascertained and estimation of water runoff established.

Because KCWA only recently decided to participate in sharing the cost of the computer aided classification of Kern County watersheds, this study's completion date must be extended to December 1978 rather than our projected April 1978 completion date. We begin, then, a years research effort this December (1977) in lieu of our anticipated May 1977 beginning date.

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Results indicate that computer aided classification of mountainous vegetation, using Landsat computer compatible tapes (CCTS) and modern remote sensing analyzing technology provides:

- The essential information about mountainous vegetation for prediction of watershed runoff;
- Data generated by remote sensing technology which will impact management decisions by the Corps of Engineers, Bureau of Reclamation, and the Soil Conservation Service.

Additionally, had NASA raw data not been available (i.e. Landsat CCTs) and had remote sensing technology not been applied to the present problem, the state agency involved would have used traditional terrestrial survey methods. This method would have been less appropriate, and hence less beneficial, for cost/benefit analysis reveals that NASA data/remote sensing technology provides the needed map product for c. \$190 per topographic quadrangle whereas terrestrial survey method cost is c. \$2300 for the same area.¹ Moreover, NASA data/remote sensing technology provides more accurate data than the present method used by the user agency as documented by the appended letter from KCWA.

¹ It must be noted that the user agency's cost estimate of c. \$2300 per topographic quadrangle for vegetation classification is predicated upon extrapolated costs incurred by KCWA in the Lake Isabella region. This region is accessible by auto and four wheel drive vehicles and has some dated air photos available. An upward adjustment of traditional survey cost would be necessary county wide, as much of the region requiring vegetation classification is unaccessable by vehicle and has no photographic coverage (or otherwise) except the NASA imagery used in this study.

GROUP	NO. OF SAMPS	PCT. CORCT	NUMBER OF SAMPLES CLASSIFIED INTO					
			GRASS1	BRUSH/GR	PASTURE	WOOD/GR2	BRUSH1	WATER
1 GRASS1	19	94.7	18	1	0	0	0	0
2 BRUSH/GR	45	95.6	2	43	0	0	0	0
3 PASTURE	27	100.0	0	0	27	0	0	0
4 WOOD/GR2	48	81.3	0	4	0	39	5	0
5 BRUSH1	25	100.0	0	0	0	0	25	0
6 WATER	90	100.0	0	0	0	0	0	90
TOTAL	254	95.3	20	48	27	39	30	90

OVERALL PERFORMANCE (242/ 254) = 95.3

AVERAGE PERFORMANCE BY CLASS (571.5/ 6) = 95.3

TABLE 1. Classification Results

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KERN COUNTY WATER AGENCY

4114 Arrow Street, P.O. Box 58

Bakersfield, California 93302



Directors

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Edna M. Purvins
Secretary

December 8, 1977

9.3.51
400-25

University of California
Department of Geography
Remote Sensing Unit
Santa Barbara, California 93106

ATTN: Robert Sasso
Dr. Jack Estes

RE: NASA Remote Sensing Program for Kern County
Water Agency Vegetative Classification

Gentlemen:

In response to your request regarding the Agency's application of the remote sensing land use technique, we have the following comments.

Thus far we have had little opportunity to apply the remote sensing technique to a specific application. This lack of application is due to the fact that we have received data only on a small watershed in the Isabella area, which was used as a ground truth site. When the Agency receives the information on additional areas as they are completed, we will begin applying it immediately. Up to now, we have been concentrating on evaluating the computer output information with respect to the ground truth data and testing the results in the Agency's hydrology equations. The remote sensing technique has proven to be feasible for the Agency's hydrology criteria with reasonable accuracy.

The vegetative information compiled by the remote sensing technique is used as a factor in our floodflow hydrology. The application of this will be used in the Agency's flood plain management program, which includes review of subdivisions, parcel maps, building permits, and design of flood control facilities.

This Agency coordinates flood control activities with other governmental Agencies. Therefore, we feel this technique

should be beneficial to such agencies as the Corps of Engineers, Bureau of Reclamation, Bureau of Land Management and Soil Conservation Services to fulfill a broad spectrum of inventory requirements for watershed management.

We feel this remote sensing technique will provide the Agency with a procedure in classifying vegetative cover at less cost and provide more accuracy than the present conventional method.

Yours very truly,

for Stuart T. Pyle
Stuart T. Pyle
Engineer-Manager

DKS:lk

APPENDIX A

Cover and Land Use for Hydrologic Soil-Cover Complexes of a Typical Watershed in Land Resource Areas 19 and 20, Southern California Coastal Plains and Southern California Mountains

For the purpose of classifying cover on a watershed in coastal and mountain areas of Southern California, the land uses shown in Chapter 9, Table 9.1 Section 4, Soil Conservation Service National Engineering Handbook, October 1971, are here modified to apply more closely to Southern California conditions. It is emphasized that the classification of land use into kinds of plant cover is intended entirely for estimating runoff.* Only those classes pertinent to the feasibility study area are listed.

Wildland

Areas with such natural or native plant cover as grass, brush, woodland-grass or woodland. It may or may not be used for grazing livestock. It includes abandoned cropland. Because the description of grassland, woods, and forest on page 8.3, Hydrologic Handbook, is too broad for application in Southern California, Wildland Land Use has been substituted and divided into the following kinds of plant cover.

Annual Grass - Areas on which the principal vegetation consists of annual grasses and weeds.

Broadleaf chaparral - Areas where the principal vegetation consists of evergreen shrubs with broad, hard, and stiff leaves. The brush cover is usually dense or moderately dense.

Meadow - Areas with seasonally high water tables, locally called cienegas, on which the principal vegetation consists of sod-forming grasses and other plants.

Narrowleaf chaparral - Areas where the principal vegetation consists of diffusely branched evergreen shrubs with fine needle-like leaves. The shrubs are widely spaced and low in growth. Where narrowleaf chaparral shrubs are dense and high, such areas will be included with Broadleaf chaparral ground cover.

Open brush - Areas on which the principal vegetation consists of soft-woody shrubs which are grayish in color. It also includes vegetation on desert-facing slopes where Broadleaf chaparral species predominate in an open shrub cover.

Perennial grass - Areas on which the principal vegetation consists of perennial grass, either native or introduced, and which grows under normal dryland conditions. It does not include irrigated and meadow grasses.

Woodland-grass - Areas with an open cover of broadleaf or coniferous trees and with the intervening ground space occupied by annual grasses or weeds. The trees may occur singly or in small clumps. Canopy density, the amount of ground surface shaded at high noon, is from twenty to fifty percent.

Woods (Woodlands) - Areas where coniferous or broadleaf trees predominate. The crown or canopy density is at least 50 percent. Open areas may have a cover of annual or perennial grasses or of brush. Herbaceous plant cover under the trees is usually sparse because of leaf or needle litter accumulation.

Barren - Areas with no, or practically no, plant cover; where 15 percent or less of the ground surface is protected by plants or litter. This includes rocklands, land destroyed by erosion, and shaped or graded land.

* Supplement to Chapter 9, Section 4 of the Soil Conservation Service National Engineering Handbook, October 1974.

CHAPTER 3

PART II

FUEL MOISTURE CONTENT ESTIMATION

Co-Principal Investigator: John E. Estes

Project Manager: Susan G. Atwater

Contributors: Michael J. Cosentino

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FUEL MOISTURE CONTENT ESTIMATION

INTRODUCTION

Two approaches are taken in this project which attempts to derive estimations of green fuel moisture content from remotely gathered reflectance data from satellites. The first approach uses reflectance values from the four MSS bands of Landsat black-and-white image transparencies. The second approach correlates Landsat CCT digital reflectance values with ground based measurements of fuel moisture content. This dual format approach was designed in consultation with U.S. Forest Service personnel of the Los Padres National Forest. It is designed to produce results employable by more than one level of user in this agency.

The U.S. Forest Service has shown great interest in the project and has cooperated freely in providing ground based fuel moisture and climatological data from their data collection sites in the study region. They have supported the project by purchasing five Landsat CCT's of the study region which correspond temporally to dates which include a wide range of moisture conditions. It is their desire to replace the present system of collecting fuel moisture data in the field with a system using Landsat reflectance data in conjunction with readily available local climatological data.

TASKS COMPLETED TO DATE

- A study region was selected which encompasses nine of the U.S.F.S. fuel moisture data collection sites in the Los Padres National Forest. The U.S.F.S. sites are representative of unique fire danger rating areas which are internally homogeneous in terms of fire potential. The study region was selected to ensure that it falls completely within one Landsat frame which then requires the purchase of only one frame of Landsat data per date of study.

- In order to select the optimum dates of Landsat for study, ground truth fuel moisture data, climatological records and the information about the quality of available Landsat data were collected and coordinated. A calendar-type matrix was developed with 1) fuel moisture readings from each collection site, 2) rainfall readings from each U.S.F.S weather data collection station, and 3) Landsat overpasses and their quality in terms of cloud cover and atmospheric. From the matrix optimum dates of imagery were selected to provide coincident ground and satellite data for analysis.
- Landsat imagery was acquired in both image and CCT formats. The Geography Remote Sensing Unit has previously acquired much of the Landsat image format data for the study region during the period when coincident ground truth data was available. As mentioned previously, the U.S. Forest Service is interested in pursuing the digital data approach and has purchased five Landsat CCT's of the region for the spring, summer and fall of 1976. This provides a sufficient amount of coincident ground and satellite data to study the entire range of fuel moisture conditions.
- Film density values were measured from Landsat transparencies of the four MSS bands for each of the nine ground truth collection sites or study sites with a Macbeth Quantalog densitometer. Values were also obtained for the 15 step grey wedge on each image; these were used to normalize the density values to one "base" date.
- The digital number for each of the study sites was obtained from each of the four MSS bands of the five Landsat CCT's using the following procedure. The study region was extracted from the tape and reformatted for use with the LARSYS computer software package. Using this software, the study sites were accurately located on enlarged digital grey maps and their digital numbers extracted.

These point reflectance values from the image and digital Landsat data will be correlated with corresponding ground truth values for fuel moisture content. It is expected that this correlation will be positive but must be refined to achieve an accurate estimation of moisture content corresponding to the three levels required by U.S.F.S. Fuel Model B, i.e.: <70%.

70-120%, >120%. Areas of refinement include:

- correction for the temporal lag of Landsat data behind ground truth data
- correction for atmospheric attenuation

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- inclusion of air temperature, rainfall and relative humidity history in the correlation.

CHAPTER 3

PART III

COTTON MAPPING FROM LANDSAT IMAGERY

Co-Principal Investigator: John E. Estes

Project Manager: Tara L. Torburn

Contributors: Larry R. Tinney

COTTON MAPPING FROM LANDSAT IMAGERY

ABSTRACT

Pink bollworm of cotton poses a major threat to California cotton production. As one part of an integrated effort to control and eradicate pink bollworms, California's Department of Food and Agriculture, in conjunction with the U.S. Department of Agriculture, maps all cotton fields within the state. This task is presently performed by automotive field surveys which are both costly and time consuming. Satellite remote sensing systems, such as NASA's Landsat series, now offer a means of acquiring this information that is potentially both more timely and economical than conventional ground based sources. The purpose of this research is to demonstrate the feasibility (stage 1) and operational utility (stage 2) of a Landsat methodology suitable for implementation by Department of Food and Agriculture personnel.

INTRODUCTION

Cotton is California's most valuable field crop and since 1974 California has been the nation's leading producer of cotton. Within California the principle cotton growing regions are the San Joaquin and Imperial Valleys, with Kern and Fresno Counties alone accounting for more than half the state's 1974 production.

Because of cotton's role in both the state and national economy (fifth most valuable U.S. export crop) the control of pests and infestations that affect cotton yield is a major agricultural concern. Unfortunately, cotton is very susceptible to attack by pests, with approximately

one half of all insecticides applied to cotton, while cotton represents only 5% of cropped acreage . The biggest threat to cotton in California is the pink bollworm, *Pectinophora gossypiella*, considered one of the world's most destructive cotton pests. First collected in California in October 1975, it has caused extensive damage to cotton in Imperial, Riverside, San Bernardino, and San Diego counties. Yield loss and control cost California growers more than \$19 million in 1974. Regulations for controlling the spread of pink bollworm within California have been established by the State Department of Food and Agriculture (Sections 3490, 3590, and 3595 of the California Administrative Code). These regulations and a Federal Domestic Quarantine (No. 52), set down guidelines for the individual farmer to follow in the planting and harvesting of cotton and are aimed towards reducing the likelihood of pink bollworm being transported or successfully overwintering in California.*

A pink bollworm sterile moth release program was begun in the Imperial Valley, California in 1966-1967, after the invasion of the pink bollworm from nearby states. In 1968, the program was expanded to the San Joaquin Valley to keep the pink bollworm from becoming established. More than 150 million sterile moths were released by USDA's Animal and Plant Health Inspection Service in the San Joaquin Valley in 1975, with more than 2,000,000

* A news release by the California Department of Food and Agriculture in late October, 1977, has changed the "plowdown" date for the San Joaquin Valley, California from February 1, 1978 to January 1, 1978. It was changed on recommendations from the Cotton Pest Control Advisory Board "to help San Joaquin Valley growers beat down what could be the beginning of an infestation of pink bollworms in the major cotton growing counties of the state."

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being released daily in 1977. To date, the results of the releases show no evidence of a reproducing population in the Valley.

To monitor the effectiveness of the sterile-release program and natural pink bollworm population levels, the California Department of Food and Agriculture (CDFA) and the U.S. Department of Agriculture (USDA) engage in trapping programs. Baited traps are set between July and October/November to catch the moth stage of the pink bollworm; presently one trap is set for each 40 acres of cotton. To assure optimum distribution of traps, maps are generated during April and May showing all cotton fields in the San Joaquin Valley. Present mapping procedures involve automotive "wind shield surveys" which are both costly and time consuming. After the location of the cotton fields has been determined, trapping districts are established, and the appropriate number of traps set and monitored throughout the growing and harvesting seasons.

REMOTE SENSING

GRSU is presently investigating the use of Landsat data for mapping cotton fields on a yearly basis (preparatory to control activities) that are capable of replacing present survey methods. Previous and ongoing research by GRSU (NGL 05-003-404 and NSG 2207) has documented the feasibility of crop identification using Landsat imagery (Figure 2). Research is presently underway to investigate the operational feasibility of generating cotton maps under the unique time constraints associated with the control program.

Preliminary manual interpretation tests to identify cotton were performed using a comprehensive set of 13 dates of Landsat imagery for the year 1974, for a selected portion of the Wheeler Ridge-Maricopa Water Storage District in southern Kern County, California. Table 2 demonstrates

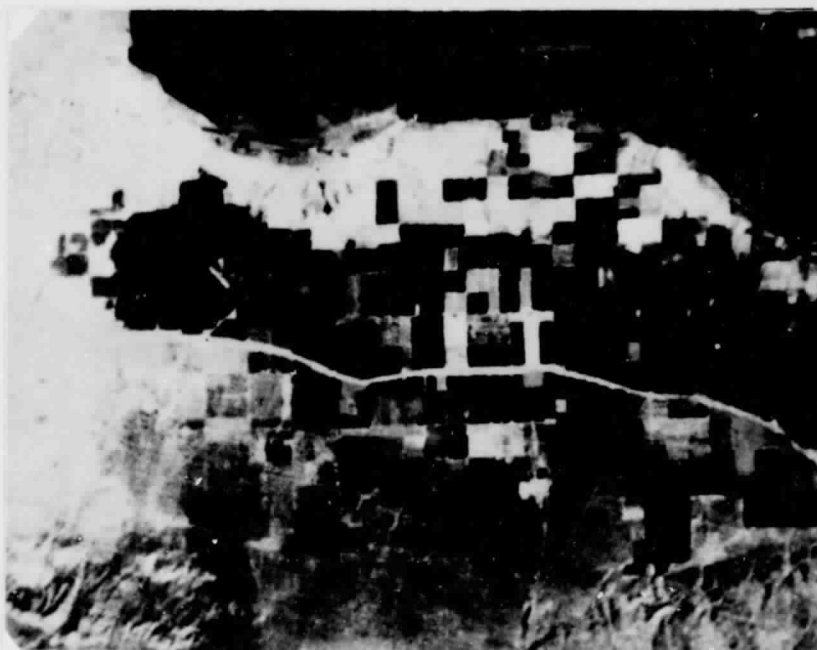


FIGURE 2. Multidate Landsat composite to enhance cotton. Landsat 1974 MSS Band 5 imagery from May 21, August 1, and September 6 were color combined to enhance cotton, which appears as various shades of blue in the composite. It is in excellent agreement with the Wheeler Ridge-Maricopa Water Storage District Crop Map.

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TABLE 2. Composite of five interpreters
for temporally unconstrained multirate test.

GROUP	NO. OF SAMPS	PCT. CORCT	NUMBER OF SAMPLES CLASSIFIED INTO	
			COTTON	NON-COTTON
COTTON	1105	94*	1044	61
NON-COTTON	789	88*	92	697
TOTAL	1894	92	1136	758

* Average of five interpreters.

TABLE 3. Individual interpretation of
temporally constrained (5/21/74) multirate test.

GROUP	NO. OF SAMPS	PCT. CORCT	NUMBER OF SAMPLES CLASSIFIED INTO	
			COTTON	NON-COTTON
COTTON	216	88	192	24
NON-COTTON	154	81	29	125
TOTAL	370	86	221	149

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cotton interpretation accuracies for a temporally unconstrained multigate test. Because of the unique time constraints, however, the operational interpretations must be constrained to imagery dates prior to June. Table 3 demonstrates an initial interpretation test using time constrained data.

The methodology proposed by GRSU involves two stages. Stage 1 is a feasibility test to be primarily accomplished using an existing Kern County data set (1973-1977 imagery and field data). Field data of the Fresno-Merced region for 1977 provided by CDFA will also be examined to evaluate signature extension problems. The use of a multiyear data set will provide an insight to year-to-year crop variations and atmospheric effects. Existing crop calendars and image keys will be reviewed and expanded to assess major confusion crops. Performance evaluations, in terms of optimal band and date selections, will be used to evaluate the feasibility of Landsat to provide cotton classification accuracies amenable to CDFA's needs.

Anticipating positive results, stage 2 of the project will involve an operational demonstration of developed techniques in the 1978 crop year. The results of this demonstration will be fully documented in a procedural manual and transferred to CDFA and USDA personnel through various training seminars.

CHAPTER 4

REMOTE SENSING APPLIED TO SELECTED RESOURCE MANAGEMENT PROBLEMS
IN SOUTHERN CALIFORNIA

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REMOTE SENSING APPLIED TO SELECTED RESOURCE MANAGEMENT PROBLEMS
IN SOUTHERN CALIFORNIA

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REMOTE SENSING APPLIED TO SELECTED RESOURCE MANAGEMENT PROBLEMS IN SOUTHERN CALIFORNIA

4.1 INTRODUCTION

4.1.1 Preface

This is our first year of full funding for studies applying remote sensing to selected resource management problems in California. Although our initial funding was delayed until the fourth month of the grant year (August), which delayed the initiation of some of the studies, we have sufficiently progressed so as to provide meaningful results to the resource managers by the end of the grant year (April).

The primary objective of this grant is to actively demonstrate the unique role that remote sensing can play in providing data to solve environmental and resource management problems, and to encourage resource managers to use remote sensing techniques in their management decisions. Specific objectives, and a reiteration of the guidelines of this grant will be found in section 3.3.

4.1.2 Summary

This report will detail the current studies including an overall description of the California Desert problem. A discussion of the types of future selected problems that we expect to pursue will be outlined in the future studies section. The final section will review some of the recent technology transfers that have taken place with the aid of NASA funding. A short summary of the report is given below:

4.1.2.1 The California Desert Resource Problem

The California Desert resource management problem has been a concern of county, state, and federal agencies for the past ten years. The worst fears have been that the California desert would become another Sahel or a barren desert like the once fertile crescent of the mid-east. The term "desertification" has even been applied to the process that has been taking place in the last twenty years in the California desert. (Desertification implies the degradation of land by both natural and human means.) Congress has recognized the problem by establishing a California Desert Conservation Area under the "Federal Land Policy and Management Act of 1976" (PL 94-579). The act is sometimes referred to as the "BLM Organic Act". The Act requires the Bureau of Land Management in concert with the state and local agencies to develop a comprehensive Management plan by 1980. The vastness and remoteness of the California desert (25 million acres/10 million Hectares) makes it utterly impossible to gather all of the necessary resource data for the plan by conventional ground survey methods within the specified time constraints. The use of remote sensing is an obvious solution for much of the resource inventory and subsequent assessment.

Specifically addressed in our studies is not just the application of remote sensing, but which techniques can best be applied. It is in this context

that we are selecting sample study areas and testing remote sensing techniques for gathering specified data. The techniques employed in these sample studies will then be transferred to the Desert Planning Staff (DPS) of the BLM for their use in completing the surveys of the entire California Desert. The three initial studies are of the sand dunes, the landforms, and development of a technique to identify candidate wilderness areas within the California desert.

4.1.2.2 Agricultural Problems

We previously reported that the California Citrus Industry had expressed considerable interest in improving annual citrus crop forecast. We have conducted an extensive background study of the data problem and have found there exists a considerable difference among the "cooperating" agencies and grower organizations in the reported number of acres of citrus in production. We have recommended that a stratified tree census be obtained through the use of remote sensing techniques. To date we have not been able to conclude a working agreement with the "cooperating" agencies. Therefore the citrus tree census study is being held in abeyance.

A problem of opportunity (further explained in the future studies section) involving the agricultural lands of California has been substituted for the citrus tree census for the agricultural study during the current year. The San Bernardino County Planning Agency has been selected by the State Office of Planning and Research to conduct a pilot study for the establishment of an Agricultural Element to the county general plan. If successful the model developed by San Bernardino County will be utilized by the other 57 counties of the state to develop their own agricultural element. While an agricultural element is not yet mandated by the state at this time, it will probably be mandated following the results of this model study. Data will be gathered regarding existing and potential agricultural lands to enable planners to manage this extremely important yet diminishing resource.

4.1.3 Transfer of Technology

An example of the long gestation period sometimes required to transfer certain remote sensing technologies to state agencies is illustrated in section 4.4. After four years of cooperation with the state Department of Water Resources (DWR) we have just recently received a request to transfer the necessary documentation to adopt the land use mapping techniques developed under our NASA funding. It is the intent of DWR to institute automated procedures for statewide land use mapping. Copies of letters from the DWR and other local agencies are included in the appendix.

4.2 CURRENT STUDIES

4.2.1 Selected Resource Management Problems of the California Desert

The California Desert Planning Staff (DPS) of the Bureau of Land Management (BLM) has been directed by Congress through the Federal Land Policy Management Act of 1976 to prepare and implement a comprehensive, long-range plan for the management, use, development, and protection of the public lands within the California Desert Conservation Area. The BLM must inventory the resources of some 16 million acres of the 25 million acres contained within the California Desert. The standard inventory techniques are far too slow to meet the deadline of 1980 for the initial management plan.

The objective of our selected studies within the California Desert is to demonstrate to BLM (and the other state and county government agencies involved) how remote sensing techniques can provide the data needed in the time limits established for completion of the project. Our demonstrations will primarily be models of selected areas from which BLM can apply the technique to the entire area.

4.2.1.0 Introduction

The California desert is located in the southeastern corner of the state (Figure 4.1). Its 25 million acres (10 million hectares) of land consists of 12½ million acres of federal land under the jurisdiction of the BLM; 3 million acres in federal military reservations; 2½ million acres in national and state park lands; and the remaining 7 million acres are in private lands. All of these lands of different ownership are intermingled in a checkerboard manner making assignment of management responsibility difficult. Fortunately, Congress has directed the BLM to inventory and assess the entire conservation area and make the data available to local, county, and state agencies to assist in planning and regulating their respective lands in mutual agreement with the federal agencies. Therefore, development of remote sensing techniques under the NASA grant will be mutually beneficial to not only BLM, but also the state and county agencies.

4.2.1.0.1 The Federal Land Policy Management Act of 1976 (PL 94-579)

Section 601 of the Act lists the following findings and provisions for protection which may serve as a background to why such an extensive study of the desert is required:

a. Findings:

"1) The California desert contains historical, scenic, archeological, environmental, biological, cultural, scientific, educational, recreational, and economic resources that are uniquely located adjacent to an area of large population;

"2) The California desert environment is a total ecosystem that is extremely fragile, easily scarred, and slowly healed;

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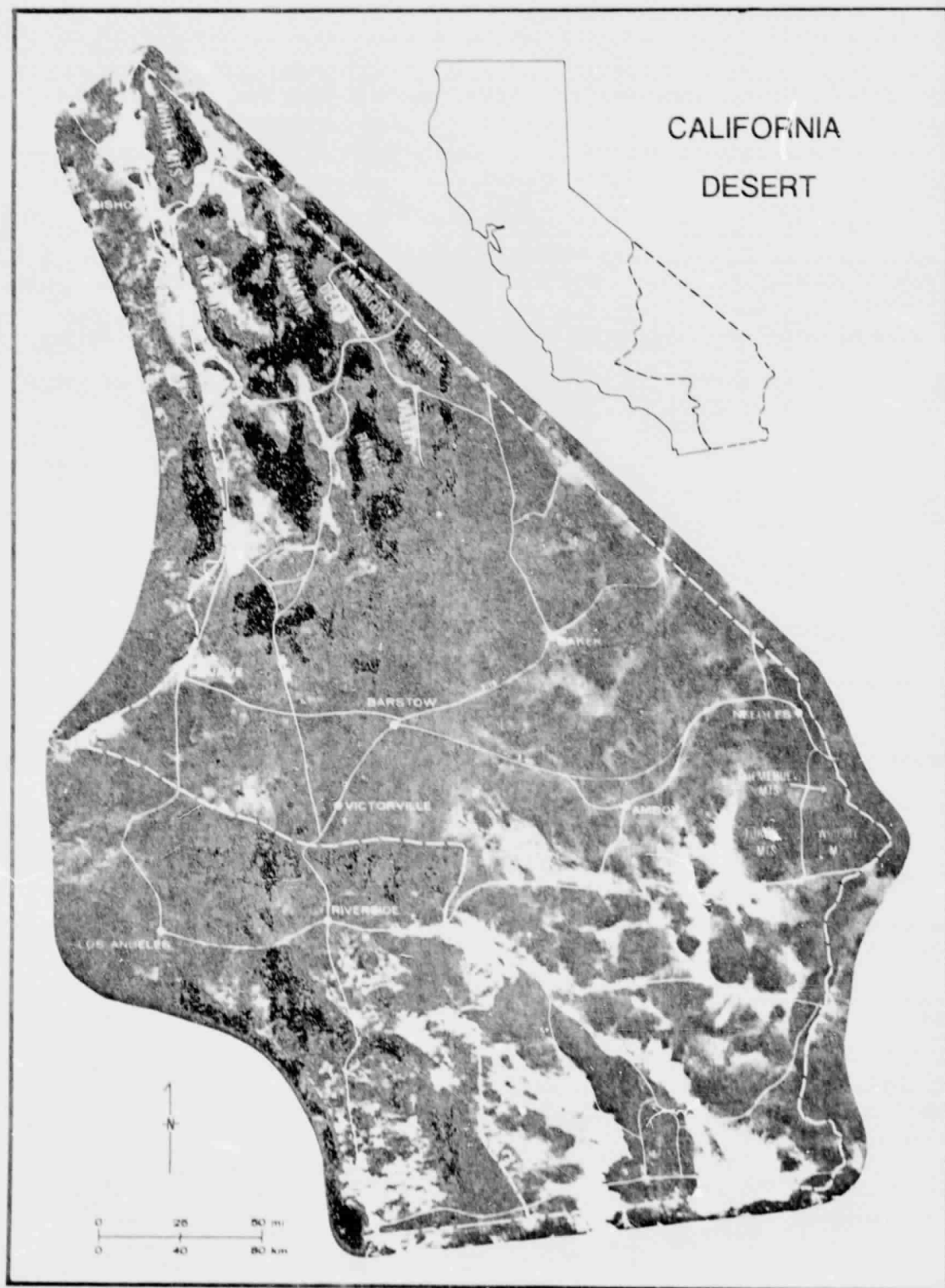


Figure 4.1

"3) The California desert environment and its resources, including certain rare and endangered species of wildlife, plants, and fishes, and numerous archeological and historic sites, are seriously threatened by air pollution, inadequate Federal management authority, and pressures of increased use, particularly recreational use, which is certain to intensify because of the rapidly growing population of southern California.

"4) The use of the California desert resources can and should be provided for in a multiple use and sustained yield management plan to conserve these resources for future generations, and to provide present and future use and enjoyment, particularly outdoor recreation uses, including the use, where appropriate, of off-road recreational vehicles (ORV's)."

b. Provisions for Protection:

"The purpose of the Act is to provide for the immediate protection and administration of the public lands in the California desert within the framework of a program of multiple use and sustained yield, and the maintenance of environmental quality."

4.2.1.0.2 Causes of Concern

As alluded to in the Act, the California desert is in close proximity to 12 million people living in the coastal basins of southern California. Until about 1960 few people ventured into the unforgiving hostile desert. The desert claimed its victims who were not prepared for its extreme climate and lack of water. Since that date modern technology has provided the masses with many types of vehicles (Air conditioned campers, trailers, tent campers, off-road vehicles, motorbikes, etc.) with which they can both withstand the rigors of the desert and engage in the destruction of the vegetation and thin layer of soils or desert pavement. The pressure of people has increased each year for both recreational and cultural activities.

Expressed earlier is the fear of desertification in which the land may eventually become one of extensive sand dunes from lack of vegetative cover or desert pavement (thin layer of rocks) to retain the soils. The destruction of archeological and historic sites is equally serious and even the governments are contributors to the destruction with expansive military bases; wide spread maneuvers and target ranges for bombs, guns, and artillery; massive communication and utility systems; and highway construction.

While humans are not responsible for the flash flooding that occurs, they are responsible for poor planning that allows construction to take place in areas of high flood risks. (e.g. Rancho Mirage fan near Palm Springs, the town of Ocotillo near Interstate 8, or the washout of Interstate 15 near Baker). Knowledge of the existence of resources and potential hazard areas will enable proper planning and management to prevent the California desert from becoming a wasteland like some of the other deserts of the world.

4.2.1.0.3 UCR Studies

The objectives of the UCR studies in remote sensing in the California desert are to show where various remote sensing techniques can provide adequate

data in time to meet the inventory deadline established by the Act and are not aimed at providing a complete inventory for BLM (that is their job). The following will describe the progress to date of various individual studies showing the potential of remote sensing to provide resource data of the California desert.

4.2.1.1. Sand Dunes Study

One of the most attractive and challenging landforms to off-road vehicles (ORV's) is sand dunes. Like many deserts, several large areas of sand dunes exist in the California desert. Some of these dunes are active, some inactive or stabilized. Many of the dune areas have been studied individually but no collective study exists. The extent of degradation of the dunes due to ORV's is not known at this time. It is also unknown which dune areas, if any, need to be restricted from ORV's due to lack of detailed information on their structure and extent. Preliminary reconnaissance indicates that it would be difficult to determine complete information concerning these dune areas from the ground due to their large extent and inaccessability in some areas. Remote sensing appears to be the best solution in obtaining complete data concerning each dune field and in fact this has proven to be the case. In many instances the source of the dune area is readily apparent; other areas require further investigation to determine their source. The results of this investigation may suggest potential areas, which if uncontrolled, may produce dune fields in the future.

4.2.1.1.1 Approach

Landsat imagery provides vital data for this study. Through the use of Landsat imagery we have mapped the extent of major active sand dune occurrences as shown in figure 4.2.1. Landsat also provides a view of the overall setting for each dune field. A field's location with relation to playas, mountains, and other dune fields can be readily interpreted from Landsat. Possible relationships can be assessed.

Through the use of Landsat imagery, U-2 imagery, and field survey, data concerning several variables have been gathered for each of the active and stabilized dune areas. These variables include: location, dune types present, areal extent, average and maximum heights of dunes, elevation above sea level, local relief, lithology of sand, mean grain size of sand, sorting coefficient of sand, direction of sand migration, direction of prevailing sand-moving wind, percentage of vegetation, and dune cover.

4.2.1.1.2 Status of Project to Date

All sand dune fields have been located, mapped, and typed. Field work is complete and the writing of the final report has begun. Evidence that some dune areas are more active today than during the recent past has been observed in the study area. Unsound agricultural practices appear to have been a contributing factor. Other fields exhibit a stability that may reflect recent changes in invading vegetation species or local climate. Table 4.1 indicates the areal extent of each dune field according to the classification scheme shown in table 4.2.

Figure 4.3 shows the Cadiz Valley and Dale Lake area sand dune fields. These fields are typical of the dune areas found in the California desert.

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TABLE 4.1
AREAS OF SAND DUNE FIELDS IN THE CALIFORNIA DESERT
(In square miles)

DUNE FIELDS	I. SIMPLE DUNES											II. COMPLEX DUNES			TOTAL	
	A. Active								B. Stabilized			A Inter- secting Transverse Series	B Whale- back	C Sand Mta.		
	1 Transverse dune Series	2 Barchan or Crescent	3 Isolated Transverse Ridges	4 Obstacle Dunes			5 Source- Bordering lee dunes	6 Sand Sheet/ Hummocks/ Blow-sand	1 Blowout- Parabolic							2 Shrub- Coppice
				a Cl	b Fall	c Long			a Reg	b El	c Ex					
1. Eureka Valley				8	2									4	19	
2. Saline Valley	10									25					35	
3. Olancha	5														5	
4. Panamint Val.								5						3	8	
5. Death Valley	25							6							31	
6. Dumont	6													10	16	
7. Kelso	130	12			6	7		235				33	30		453	
8. Barstow Area				16	3			45	80			7			151	
9. Antelope Val.				1	1			264	51						317	
10. Lucerne Valley								100	2						102	
11. Dale Lake Area	25					45		30		16					116	
12. Cadiz Valley	60			40				325	14						439	
13. Rice Valley	27			4		325		65	21						442	
14. Chuckwalla V.	120		2	2				160	10						294	
15. Coachella Val.	5							65				22			92	
16. Salton Sea B.		12													12	
17. Imperial	555							2	231				55	203	1046	
TOTALS	973	24	2	71	12	377	0	1302	434	16	0	62	85	203	3578	

LEGEND

SAND DUNE FIELDS IN THE CALIFORNIA DESERT

- | | |
|----|----------------------|
| 1 | EUREKA VALLEY |
| 2 | SALINE VALLEY |
| 3 | OLANCHA |
| 4 | PANAMINT VALLEY |
| 5 | DEATH VALLEY |
| 6 | DUMONT |
| 7 | KELSO |
| 8 | BARSTOW AREA |
| 9 | ANTELOPE VALLEY AREA |
| 10 | LUCERNE VALLEY AREA |
| 11 | DALE LAKE AREA |
| 12 | CADIZ VALLEY |
| 13 | RICE VALLEY |
| 14 | CHUCKWALLA VALLEY |
| 15 | COACHELLA VALLEY |
| 16 | SALTON SEA BARCHANS |
| 17 | IMPERIAL |

Figure 4.2a

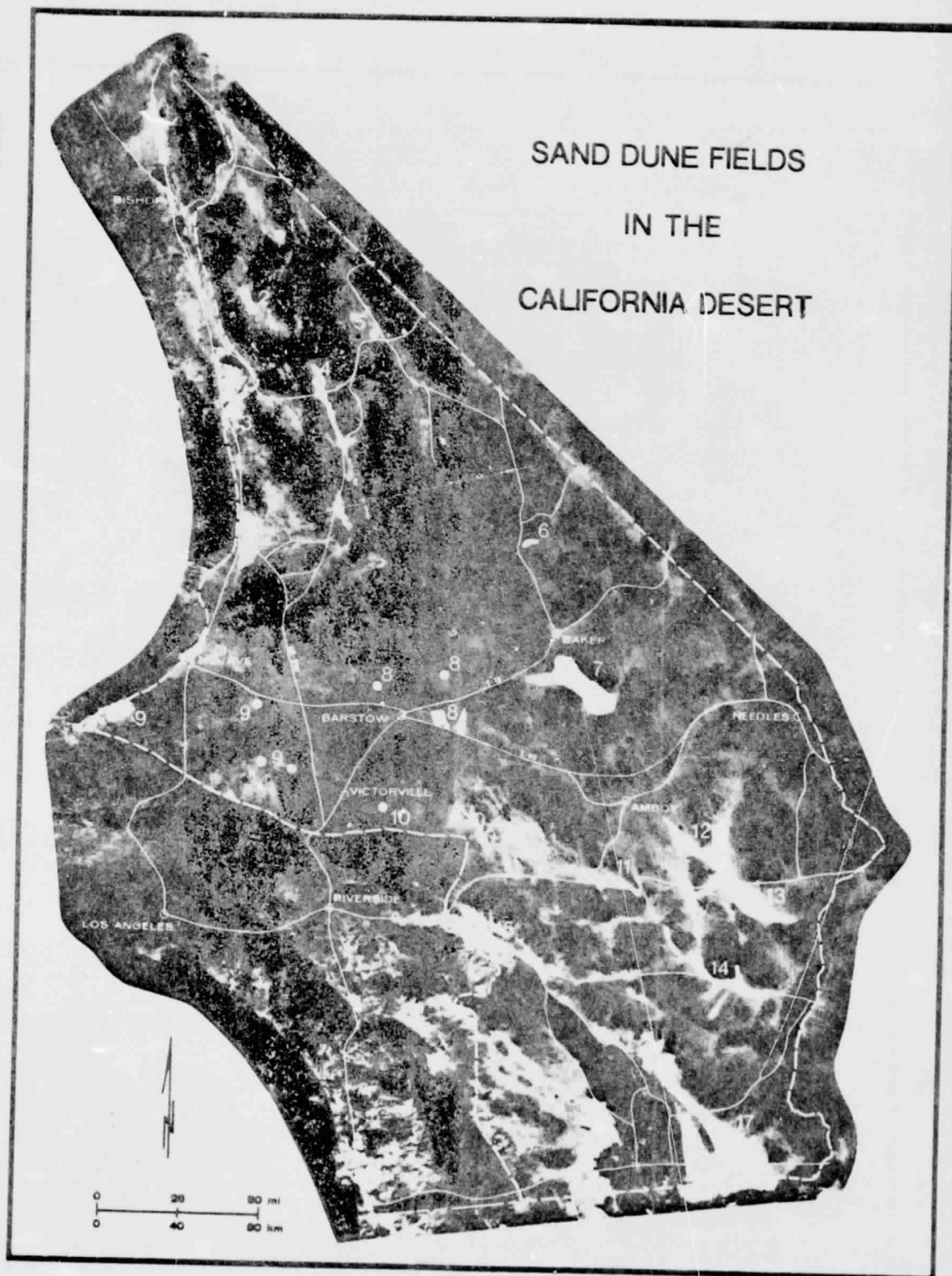


Figure 4.2b

TABLE 4.2
SAND DUNE CLASSIFICATION

I. SIMPLE DUNES

A. Active

1. Transverse dune series
2. Barchan/crescent
3. Isolated transverse ridge
4. Obstacle
 - a. climbing sand sheet
 - b. falling sand sheet
 - c. longitudinal
5. Source bordering lee
6. Sand sheet

B. Stabilized

1. Parabolic blowout
 - a. regular
 - b. elongate
 - c. extreme
2. Shrub-coppice

II. COMPLEX DUNES

- A. Intersecting Transverse Series
- B. Whaleback
- C. Sand Mountains

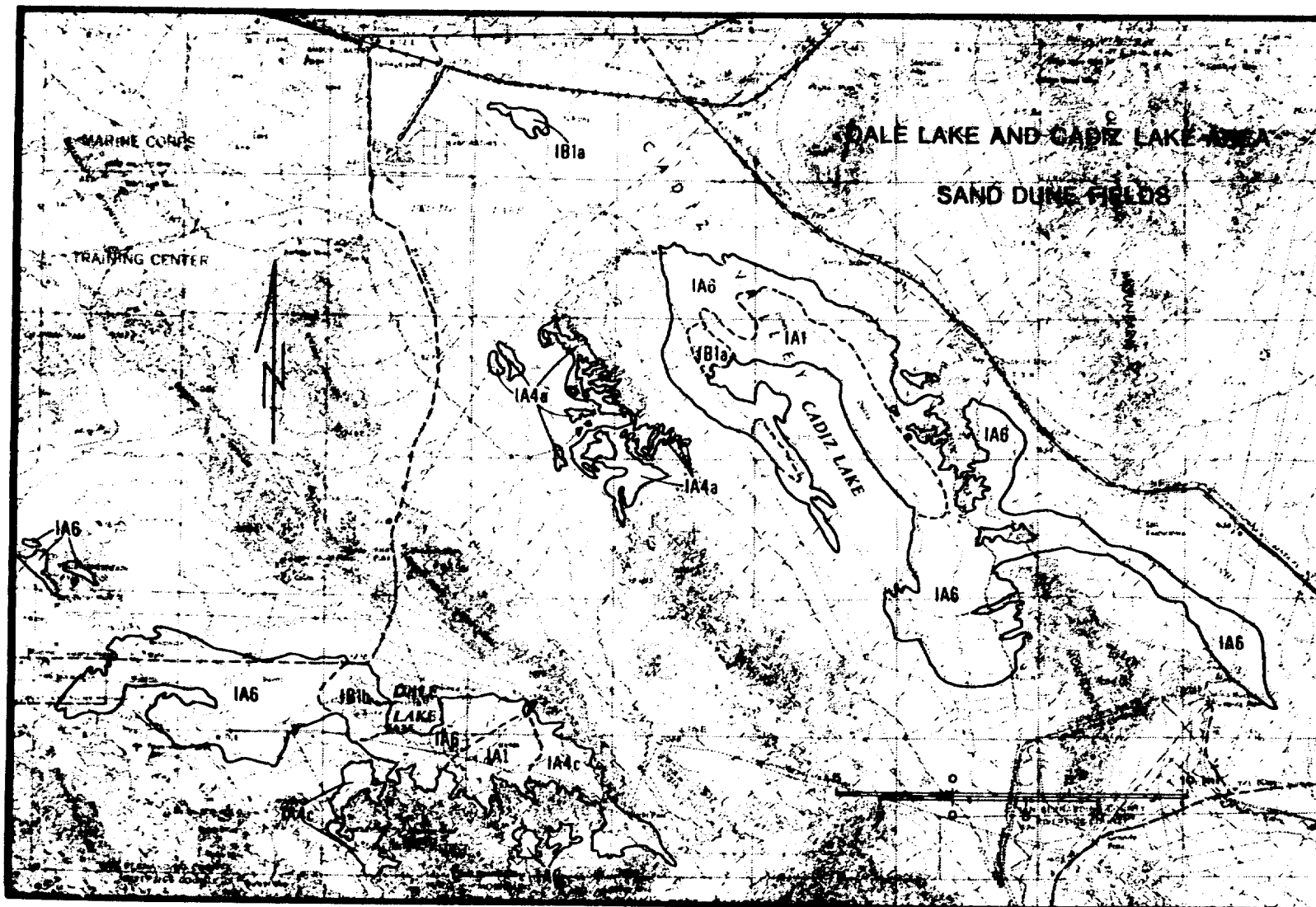


Figure 4.3

4.2.1.1.3 Anticipated Results

The final report will provide managers or users of the California desert with the environmental data necessary to establish regulations for the practical and efficient utilization of the sand dune resources. Areas of potential sand encroachment will receive special attention and the general wind circulation patterns may be interpreted from analysis of the collective dune fields. General climatic factors such as prevailing winds and relative wind velocities are virtually unknown for large areas of the California desert.

4.2.1.2 Landform Study

4.2.1.2.1 Objectives

The prime objective of this study is to conduct a partial landform reconnaissance of the Southern California Desert (Figure 4.1) with the aim of generating: 1) selected landform maps at the scale of 1:250,000; and 2) a methodology to be followed by BLM personnel or contractors for landform mapping purposes. A general landform map and classification system can be used in both: 1) further geomorphological studies on a firm scale; and 2) studies of landform-related elements such as soil vegetation and archaeology.

Recent studies attempting to classify soil types by spectral analysis have shown that collateral data are necessary to differentiate some soils which have the same spectral response. The studies have shown that certain soils with the same spectral response can be differentiated by correlating them with the underlying landform. Two recent soils inventories could not be completed until a detailed landform map of the areas were completed to provide the necessary correlations. Before the Desert-Wide Inventory is completed and assessed it will be necessary to have a complete landform map of the California desert.

One would anticipate that a physical relief map or topographic sheet could be used to provide the necessary landform data. Unfortunately, both the relief map and the topographic map indicate only ill-defined areas identified as mountains, valleys, playas, washes, etc. along with the colloquial name given them by past inhabitants or travelers in the region. The lack of boundaries between these features makes them far too gross to correlate with soils or vegetation. Efforts have also been made to determine if anyone has previously prepared a landform map of the California desert. It is probable that no such effort has been previously undertaken because of the lack of available adequate imagery. Landsat imagery of the area has only been in existence for five years and only recently has there been complete high-altitude U-2 imagery available.

The value of using remotely sensed imagery in studying physical as well as cultural phenomena is no longer questioned. What remains somewhat unclear, however, is the type and scale of imagery best suited for specific types of studies and the problems inherent in the application of a technique to a specific study. The examination of the applicability of high-altitude U-2 imagery to landform mapping and the identification of problems associated with landform mapping using air-photographs are secondary objectives.

4.2.1.2.2 Methodology

At an early stage, U-2 frames from different locations representing a wide range of geomorphological environments were studied in order to obtain a general overview of the high diversity of landforms characterizing the study area. Once familiarity with the area was achieved, a tentative classification was established and applied in delineating landform categories. Collateral information was used from both, low altitude imagery and field investigations. This was done in order to confirm the delineation and fully describe the characteristics of each category. Consultation with potential users of the product assisted in improving the classification, for future practical use, as well as contributing to scale determination.

Once the classification was established systematic mapping commenced. Most of the area was mapped using separate frames of CIR imagery 9" x 9" format at a scale of 1:130,000. Various areas for which no coverage of U-2 imagery was available were mapped at other scales. Finally all frames were reduced and incorporated into maps based on the topographical sheets at the scale of 1:250,000.

A complete landform map was established for the areas under study within the Needles Sheet. Frame coverage is also identified so that reference to the film as well as to the original mapping is possible.

4.2.1.2.3 Conclusions

A workable classification based on strict topographical characteristics is provided. Genetic and lithological criteria were avoided. Genetic and lithological terms were used only where necessary for full comprehension. However, a high degree of correlation between categories employed and genetically defined landforms was maintained throughout the classification.

The suitability of U-2 imagery for the purpose of landform mapping has previously been demonstrated. This study has shown the level of classification detail possible based on this imagery. The final map at the scale of 1:250,000 differs from the original mapped frames at the scale at 1:130,000 only by being slightly more generalized. No further detailed landform categories could have been applied at the larger scale.

4.2.1.2.3 Classification

The proposed classification is based on two topographical elements: 1) the general slope; and 2) the degree of incision. The general slope, as the term implies, refers to the general slope between the highest and lowest locations within the category delineated. The degree of incision has two components: 1) magnitude; and 2) frequency. Magnitude refers to the depth of incision while frequency accounts for how often the incisions occur in the horizontal dimension. Occasionally slopes of the incised valleys are also described. Exceptions are the sand dune categories where the above mentioned elements refer to the topographical characteristics of the sand hills and not to the intervening depressions.

As a rule, the classification tries to avoid definitions based on genetic or lithologic criteria. However, wherever a perfect correlation between a category's characteristics and a genetic landform term was found the term was used for convenience.

Following is a detailed description of the classifications developed and applied in this study to both field observations and photo interpretation.

Playa: Dry playa (Pd) are characterized by nearly horizontal surfaces (0-1% slope) which are poorly drained, usually saline and covered with water after floods.

Moist playas (Pm) are areas characterized by horizontal surfaces with salt crusts underlain by a constantly moist layer that fluctuates seasonally and the areal extent of which varies seasonally.

The only difference between the two categories is the exposure of a water table at the surface. Unlike the dry playa, which is water-covered only after floods, the moist playa is throughout the year. Consequently the two categories differ from one another by their micro-relief and other physical properties which are undetectable from U-2 imagery.

Plain: Undifferentiated Plains (P) are areas characterized by nearly level surfaces (1-3% slope) with shallow (1-6 ft.) topographic irregularities but not further differentiated.

Sand covered plains (Ps) are plains covered by a thin veneer of sand.

Cultivated plains (Pc) are cultivated flood plains and depositional basins characterized by man-induced topographic irregularities.

Genetically, plains within the study area fall under three undifferentiated subcategories: 1) plains surrounding playas at the bottom of a topographical basin, 2) flood-plains along the Colorado River; and 3) plains occupying the margins of the receding Salton Sea. The Colorado flood-plains and plains adjacent to playas are characterized by very gentle surfaces (1%) while plains around the Salton Sea and those located topographically higher than the playas are characterized by a more pronounced slope (3%). Naturally these slight differences are detectable only in careful field observation.

The three subcategories differ from one another also with regard to their degree of incision. The plains around the Salton Sea are transversed by deeply (6 feet) incised gullies. The Colorado flood-plains are incised to a lesser degree and those around playas are barely incised.

The category of cultivated plain, although not a natural landform, was introduced in view of large cultivated areas in the study area.

Riverwash: Riverwashes undifferentiated (R) are characterized by wide (15-40 ft.) braided channels, with minor (1-4 ft.) topographic irregularities occurring 3-4 times per hundred feet.

The mapping of the riverwash category was limited to a great extent by the mapping scale. Its appearance on the final maps was possible only when riverwashes were wide. This category was not delineated separately wherever it appeared within a different category of which it is a characteristic by definition (i.e. alluvial fan).

Sand Dune: Undifferentiated Sand dunes (S) are characterized by a cover of wind blown sand, often stabilized lacking a regular geometric or topographic form.

Longitudinal dunes (Sl) are characterized by longitudinal ridges with a length several times greater than their width (40-80 ft.), commonly with a slipface on one side. Frequency of occurrence varies from 8-20 ridges per mile.

Crescentic dunes (Sc) are sand ridges composed of segments, each of which is crescentic with its length equal to or nearly equal to its width (50-200 ft.). The crescentic segments are aligned in symmetrical wavy ridges with a frequency of occurrence of 15-30 per mile.

Barchans (Sb) are sand hills, crescentic in plan, with a gentle windward slope (15-20%) and a steep slipface (34-40%), with or without contact between adjacent dunes.

The undifferentiated category comprises primarily sand sheets but also includes unmappable dunes from other categories. Complex sand dune forms were not differentiated. A separate study conducted simultaneously to this one studies them in detail (See section 3.2.2.1). Sand, as a landform category, appears also in conjunction with other landform categories where sand is overlying a detectable landform, but yet, not in large quantity as to alter its original characteristics.

Alluvial Fan: Fans (F) are characterized by gently sloping surfaces (3-7%, slide slopes up to 12%), minor vertical topographical irregularities (1-3 ft.), occurring with a frequency of 30-50 per mile and narrow interfluvial surfaces (less than 40 ft.).

This category is comprised primarily of active fans the surfaces of which are characterized by a maze of active and nonactive riverwashes (less than 40%). The category also includes non-active fans the surface of which has not been dissected. Also included in this category are unmappable areas of Fd (less than 15%) and T (less than 10%) at the foot of a receded slope.

Sand covered fans (Fs) are fans covered by a thin veneer of sand (1-2 ft.).

Both fan categories are occasionally characterized by a dominant stream entrenched at the fan's apex.

Dissected fans (Fd) are characterized by a gently sloping surface (up to 15%), major vertical topographic irregularities (5-20 ft.) with a frequency of occurrence of 15-20 per mile, and wide interfluvial surfaces (50-400 ft.).

This category is comprised primarily of non-active fans the surfaces of which have been dissected. The category includes also mud-flows, recently uplifted fans, margins of non-dissected fans along incised channels, river-terraces and unmappable areas of T (less than 10%) at the foot of a receded hill.

Sand covered dissected fans (Fds) are dissected fans covered by a thin veneer of sand (1-2 ft.).

Highly dissected fans (Fh) are characterized by gentle to moderately steep slopes (10-25%), deeply incised stream valleys (15-60 ft.) with moderately steep slopes (25-30%). Frequency of occurrence is 6-10 stream valleys per mile with narrow (less than 200 ft.) interfluvial surfaces.

All alluvial fan categories include unmappable erosional remnants composed of either bedrock or old alluvium.

Badland: Badlands (B) are characterized by a high density of gullies and ravines (greater than 15 miles per square mile) and intervening "sawtooth" ridges.

Pediment: Pediments (T) are characterized by a slightly inclined rock plain (7-18%), residual knobs of bedrock, a thin veneer of alluvium and colluvium (1-3 ft.). Minor to major (3-15 ft.), moderately steep (10-40%) topographic irregularities occur with a frequency of 5-20 per mile.

Sand covered pediments (Ts) are pediments covered by a thin veneer of sand (1-2 ft.).

These categories include up to 80% exposed bedrock.

Plateau: Mesas (Pl) are characterized by cliff-bounded, level to gently sloping surfaces (1-2%), often dissected.

Tilted plateaus (Pt) are characterized by a single or series of gently to moderately sloping surfaces (5-20%) with intervening very steep to vertical escarpments.

Hill: Hills (H) are dominated (more than 80%) by local relief of less than 300 ft., moderately steep to steep slopes (30-50%) and somewhat rounded outline. Also in this category are erosional remnants and dissected fans with local relief in excess of 100 ft.

Sand covered hills (Hs) are low hills (up to 30 ft.) covered with sand of varying depths, and high hills (up to 100 ft.) partially covered with sand.

Mountains: Mountains (M) are dominated (more than 80%) by local relief in excess of 500 ft., steep to very steep slopes (more than 50%) and rugged summits.

Lava Flow: Lava flows (L) are characterized by rough, rubbly and hummocky, poorly drained, gently sloping surfaces (1-5%), occasionally cliff-bounded.

4.2.1.3 Candidate Wilderness Area Identification

The FLM Organic Act directed the BLM to establish candidate wilderness areas in the California desert. There are large areas of the California desert which are inaccessible by most motor vehicles and would thus seem to qualify for wilderness designation.

As with analysis of other resources in the desert, it would be impossible to thoroughly evaluate all areas by field methods alone. The purpose of this study is to devise a methodology, utilizing remote sensing, which the BLM can employ to identify candidate wilderness areas. This methodology must prove of use in the identification and classification of roads and other human incursions.

The Organic Act states that "wilderness area" is defined as in the "Wilderness Act" (Public Law 88-577 EZ, September 3, 1964 78 Stat. 890). Succinctly worded, in order to qualify as a wilderness area, a region must be more or less in a natural state and must be a roadless area of at least 5,000 acres or "is of sufficient size to make practical its preservation and use in an unimproved condition". This definition raises the question as to just what constitutes a "road" and a "roadless area". A legal definition of the latter was found in the Code of Federal Regulations, Title 43, revised as of October 1, 1976. Basically, a roadless area must have the general characteristics of a wilderness and within it there is no improved road suitable for public travel by means of four-wheeled vehicles intended primarily for highway use.

With an idea of the general nature of the problem, the next step was to select an area of study and evaluate the contribution from different types of remote sensing as well as other sources. The BLM had crudely outlined a number of candidate wilderness areas. One of these areas was selected to apply the techniques and perform a detailed analysis of the area in the context of the legal definitions described above. The first candidate area chosen was the Granite-Sidewinder Mountains area near Apple Valley (figure 4.4). This area is of medium size and is located relatively close to UCR, minimizing field costs for this initial study.

The major task of the study was to locate all roads, mining scars, isolated structures or other human incursions. A base map was constructed of a mosaic of U.S.G.S. 15' quadrangles (scale 1:62,500). Data sources gathered were: 1) Automobile Club of Southern California (AAA) road maps; 2) U.S.G.S. topographic maps; 3) NASA U-2 high altitude color infra-red imagery, 1:130,000 and; 4) BLM natural color low-altitude conventional aerial photography.

Little information was available on the AAA maps--merely a few of the major roads and mines (figure 4.5). Topographic maps were more useful, showing many primitive roads, mining features and isolated buildings (figure 4.6). The conventional aerial photographs were of little value because of age (flown in the early 1950's), distortion and very poor resolution.

The most valuable source by far was NASA U-2 imagery. A large number of dirt roads were detected, some of them very crude. Something of the quality of these roads could be seen and they were classified as: 1) readily traversable by conventional vehicles (intended primarily for highway use); 2) traversable

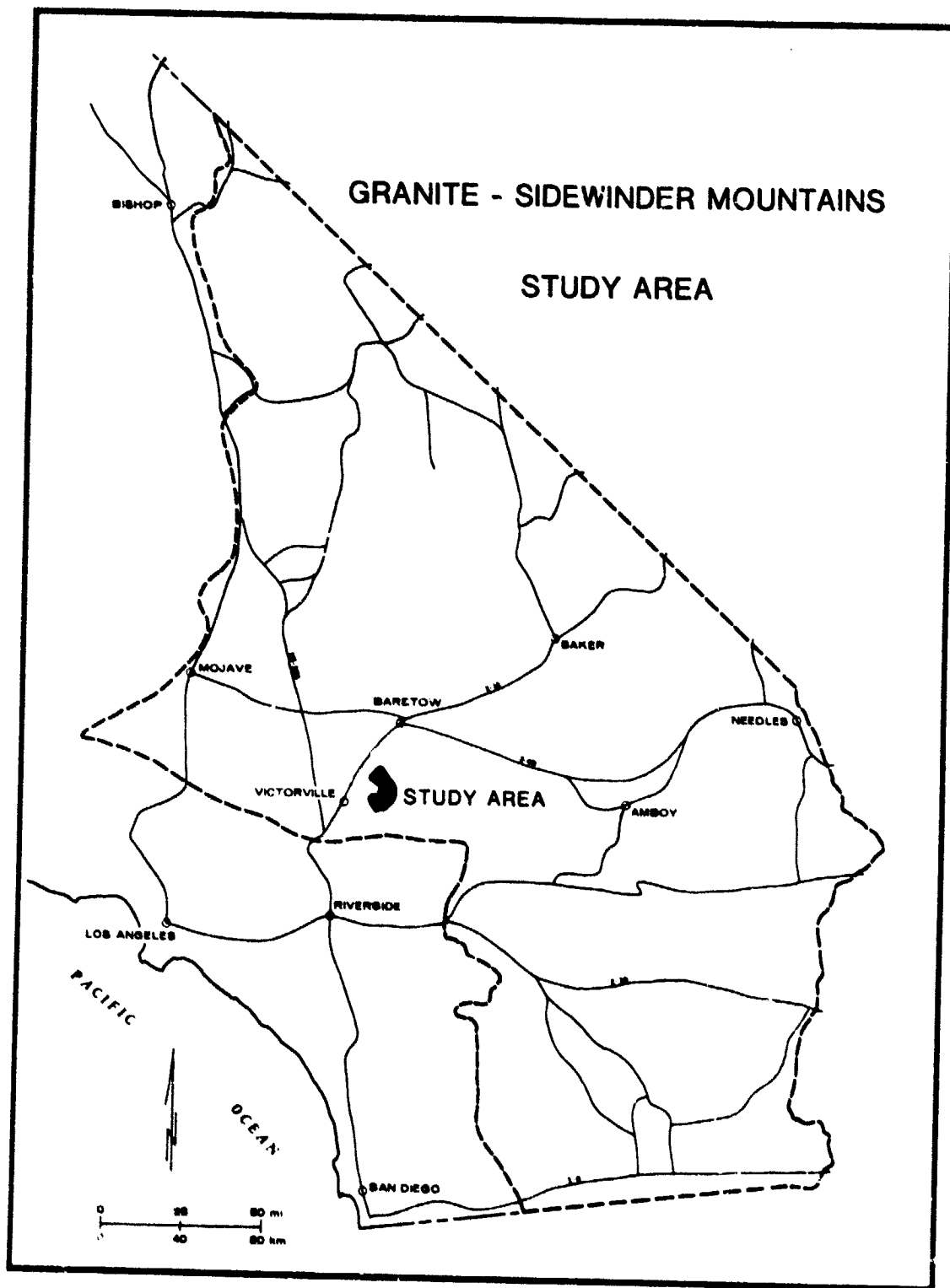


Figure 4.4

GRANITE-SIDEWINDER MOUNTAINS STUDY AREA

Road network as defined by the
American Automobile Association

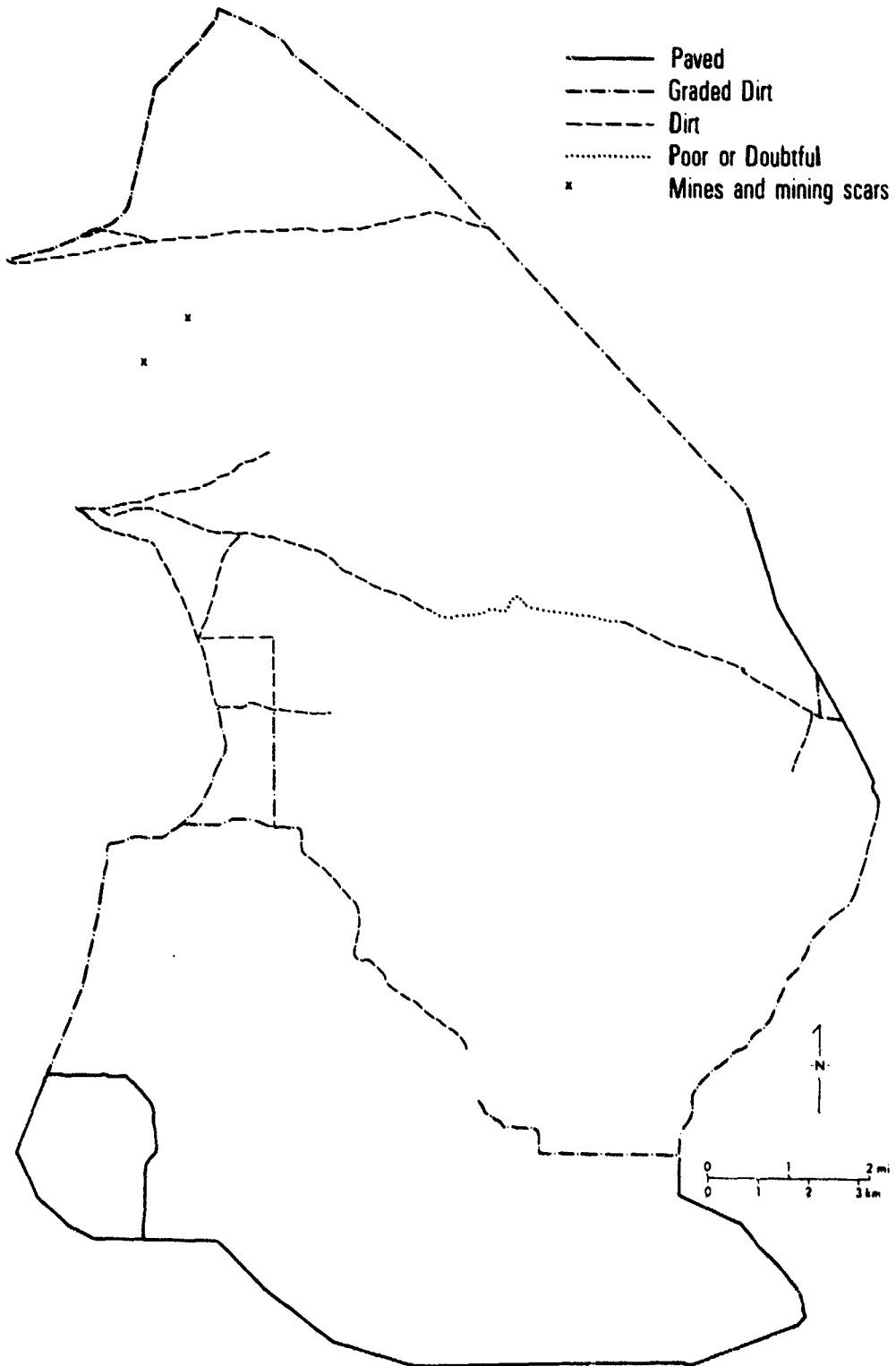


Figure 4.5

GRANITE-SIDEWINDER MOUNTAINS STUDY AREA

Road network as defined on
U.S.G.S. 15' Topographic maps

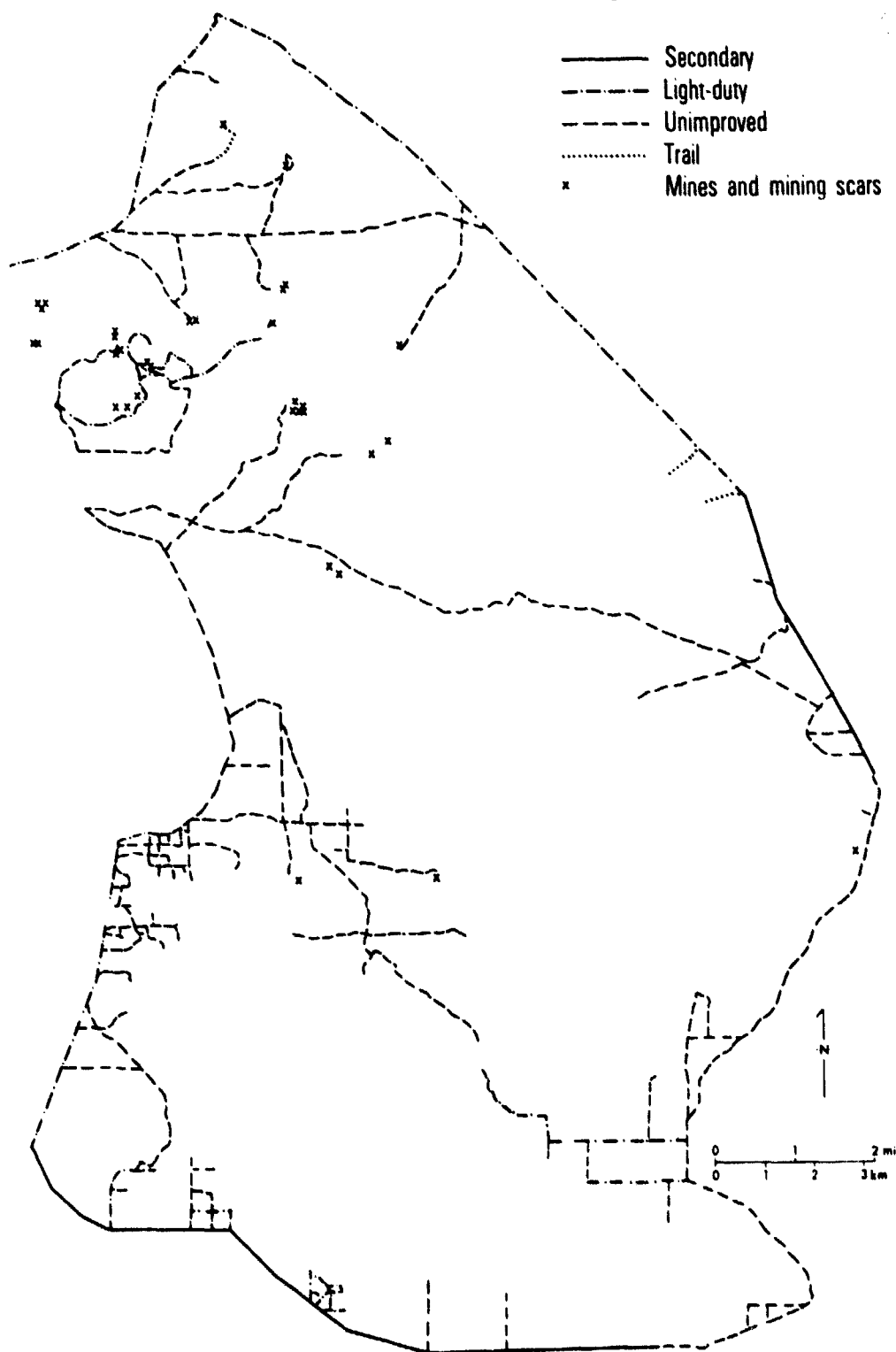


Figure 4.6

by conventional vehicles but only with caution and; 3) traversable by four-wheel drive vehicle only. Many mines, prospects and kindred excavations were visible, as were houses. It was interesting to observe that some of the features on the topographic maps, such as the alignment of roads, were found to be inaccurate when compared to the U-2 imagery which revealed far more information and in greater accuracy than the other sources (figure 4.7).

Several field trips were made to verify laboratory work. No gross errors of interpretation were found, but some discrepancies did exist. One prospect was found that was not seen in the imagery. A few additional roads were observed in the field that were later located on the U-2 imagery. The road classification was generally correct, but there were some misinterpretations. A few roads that appeared to be easily negotiable for any vehicle were found to be more rugged than expected. Overall the field check revealed that the interpretation, based primarily on U-2 imagery, was extremely accurate.

Figure 4.8 shows the road network mapped using all sources and including field reconnaissance. This is the basic data to which must be applied the definition of a wilderness area. Two criteria were used to delineate polygons of candidate wilderness area: 1) that the wilderness area could include no roads; and 2) that no wilderness area could include any roads that were not passable by a conventional four-wheel vehicle intended primarily for highway use. In both cases the delineation was based on a one half mile proximity to the nearest road. These delineations are shown in figure 4.8. As can be seen in the map the analysis resulted in three discrete regions being wilderness area candidates. The acreage breakdown according to the two criteria is as follows:

	Criterion 1	Criterion 2
NORTH	4450 acres	6000 acres
CENTRAL	7960	9560
SOUTH	<u>4465</u>	<u>5385</u>
TOTAL	16875 acres	20945 acres

The methodology and information presented here as a result of this study demonstrates that high-altitude imagery can be of great benefit to the BLM resource managers in candidate wilderness area identification. In addition, no special skills, techniques or equipment are required to perform this analysis. It is unlikely that an analysis with this accuracy could be performed using non-remote sensing techniques without incurring great costs. The methodology presented here is also flexible enough in that it can provide the basic data necessary to make decisions under a variety of delineation criteria.

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GRANITE-SIDEWINDER MOUNTAINS STUDY AREA

Road network as mapped from
NASA U-2 imagery

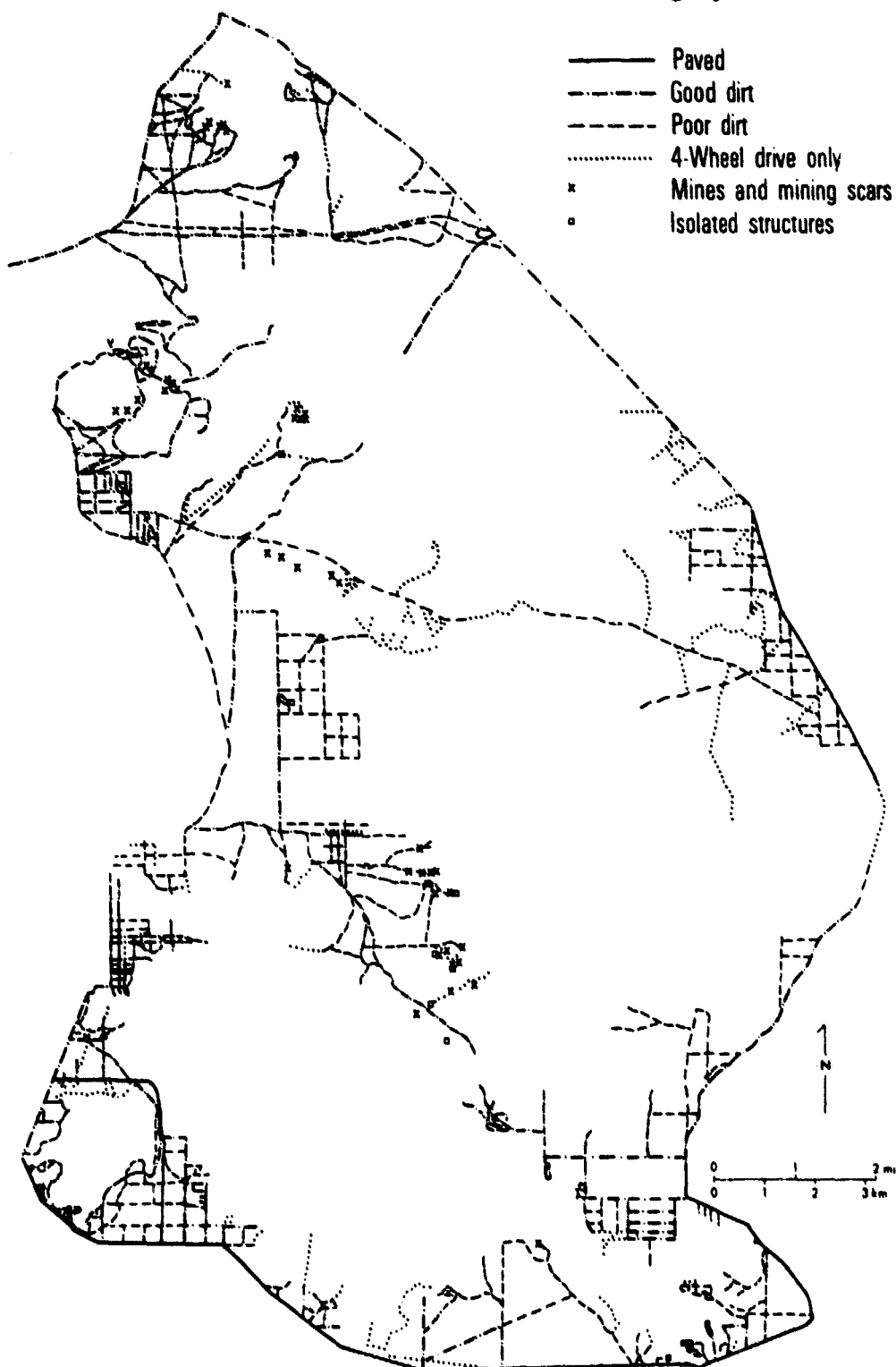


Figure 4.7

GRANITE-SIDEWINDER MOUNTAINS STUDY AREA

Composite road network and
candidate wilderness areas

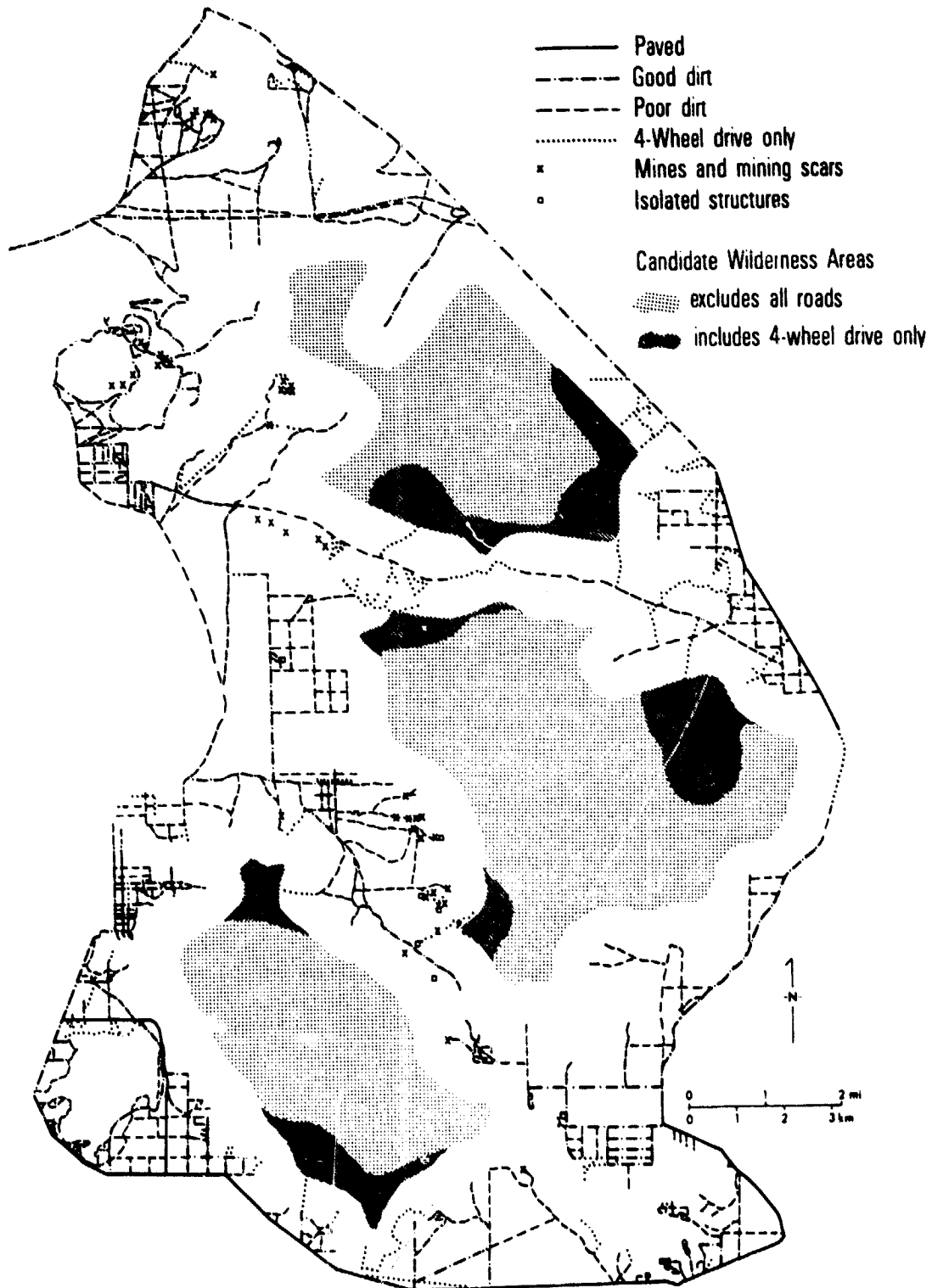


Figure 4.8

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4.2.2 Selected Resource Management Problems in California Agriculture

Two current problems dealing directly with the management of agricultural resources within the state of California have captured our attention. The first problem is concerned with the improvement of the annual citrus crop forecast and although we are not fully committed to this problem, as will be indicated below, we have conducted sufficient preliminary investigations to confirm a serious problem does exist that can be helped by remote sensing. The second problem has arisen from the concern of state agencies, as well as the governor of the state, for the rapid decline in prime agricultural lands. Consideration is being given to mandating an agricultural element in each of the county General Plans to help preserve the agricultural industry within the state. Detailed discussion of each of these agricultural problems is given below.

4.2.2.1 Determination of Stratified Citrus Tree Census by use of Remote Sensing Techniques

4.2.2.1.1 Introduction

In the Fall of 1976 we were approached by some members of the citrus industry and were asked if remote sensing techniques could improve the California citrus crop forecast. We believe the answer to be yes. For example, the Florida citrus crop forecast has been made with the assistance of a bi-annual aerial survey since 1965 with consistent 95% accuracy, but at a cost of 1 mil per box for the aerial survey and 1 mil per box for the associated objective measurement performed on the ground. The response leads to many more questions than it answers. Obviously the industry would want to know how much such a system would cost in California and can accurate forecasts be obtained with remote sensing methods if the objective measurement method was not used? Also, considerable new remote sensing technology has been developed since 1965 and these new technologies should be investigated to determine if they could increase the accuracy and/or reduce the cost of obtaining remotely sensed data.

In background investigations for this proposal it has been noted that the tree count is reported as either bearing or non-bearing trees. A cursory scan of imagery of some sample citrus groves indicates that remote sensing data may be able to provide stratified data of the tree census (e.g. four or more classifications of tree crown size that might be equated to the age of various trees within the same block). Our experience in developing an automated Geographic Information Systems has called our attention to the apparent lack

of and the possible application of an automated Citrus Information System. Perhaps there is no need for automation within the industry for the record keeping, but it is felt that the possibility for the development of an automated system should be explored in parallel with the application of remote sensing technology. We believe the citrus industry needs answers to the above questions and can benefit from an investigation on the possible alternatives available from remote sensing and automated information systems.

4.2.2.1.2 Objectives

The objective of this proposal is to determine the feasibility, usefulness, cost, and ramifications of utilizing remote sensing techniques in the California-Arizona citrus crop forecasting procedures. Specific objectives are:

1. Develop a method to obtain an annual stratified citrus tree census by remote sensing techniques which will be more current, accurate, and reliable than existing methods presently being used by the citrus industry.
2. Determine the annual cost to obtain citrus crop forecast data by means of remote sensing for the entire California-Arizona production districts.
3. Conduct a feasibility study to determine the need and usefulness of an automated Citrus Information System.

4.2.2.1.3 Approach

To achieve the objectives outlined in section 4.3.1.1. it is proposed that UCR investigators working in close cooperation with personnel presently collecting citrus crop forecast data proceed as follows:

1. Select a Sample Survey Area

To provide a sample that can be used to extrapolate the results to the entire California-Arizona Citrus Producing Districts, a sub-area will be selected (e.g. a county). The unit selected should be at a reporting level to which the results of the remote sensing analysis can be directly compared.

2. Acquire Remotely Sensed Imagery from Three Altitudes

To permit determination of how often and at what cost a remote sensing survey must be flown to provide an annual citrus tree census we will acquire imagery data from three altitudes.

a) Low Altitude Aerial Survey

To obtain a complete tree census low altitude aerial surveys will be flown at three flight altitudes to determine the most cost effective level which will still achieve the desired tree census accuracy along with

coincidental acreage calculations. The flights will be flown with color infrared (CIR) film to enable investigators to determine if other useful data can be obtained. The low altitude flight surveys should provide: 1) tree count, 2) acreage calculations, 3) cost of obtaining the tree census, and 4) evidence of the feasibility of stratifying the tree census.

b) High Altitude U-2 Imagery

The availability of NASA flown U-2 high altitude imagery of most of California will provide an opportunity to evaluate its usefulness and accuracy in determining a citrus tree census and coincidental acreage. It is believed that high altitude imagery can be used in alternate years with low altitude imagery to provide a more cost effective annual citrus tree census.

c) Satellite Imagery

NASA provides imagery data to the public from two earth resources satellites (Landsat I & II) that image all areas of California every nine days. Landsat imagery will be evaluated to determine its usefulness in monitoring the total citrus acreage and its potential to provide a change detection alert system. It may be found that Landsat can detect the removal of citrus blocks of ten acres or more and alert the forecasters to make a closer ground inspection, if this information is not already known.

4.2.2.1.4 Summary

The anticipated results of the project will:

- 1) Determine how accurate a citrus tree census is when obtained from remote sensing and compare the accuracy to present methods.
- 2) Determine the optimum remote sensing techniques for obtaining an annual citrus tree census and the best cost-benefit ratio.
- 3) Determine the annual cost of obtaining an annual citrus tree census for the entire California-Arizona Districts.
- 4) Determine the feasibility of stratifying the citrus tree census.
- 5) Determine the need and usefulness of a Citrus Information System and estimate the cost of operation.

4.2.2.1.5 Progress To Date

Studies have been performed to ascertain that a problem does exist within the current citrus crop forecast methods that could be improved by remote sensing. We found that the U.S.D.A. Crop and Livestock Reporting Service is responsible for collecting citrus census data and making the official crop forecast. However, the various citrus advisory committees who are responsible for allocating the flow of the citrus crop to market make their own independent forecasts based upon data received in addition to that reported by the C & LRS Service. A third forecast is independently made by the various growers associations such as Sunkist.

The data from which all of these forecasts are made comes from various sources, but the main basis is that reported by the C & LS reporting service. An "accurate" citrus crop census is performed by the C & LS reporting service on a quadrennial basis through each of the county agricultural commissioners. The commissioners are expected to keep the data current by periodic inspections or other sources of knowledge. The users of the data from the county commissioners are verified to some extent by the citrus boards in their market allocations, but they accept the commissioner's report as accurate. It is obvious from our limited investigations there is a great need for more accurate citrus production data to include a stratified tree census.

The manager of the citrus advisory board has been presented with the proposal outlined above and enthusiastically endorsed the proposal. However, he has been unable to receive approval from the Citrus Advisory Board which has the responsibility of coordinating citrus research projects. Therefore, this proposal is being held in abeyance until we receive a more positive confirmation from the citrus industry that they will adopt remote sensing techniques if they prove to be more accurate and economical.

4.2.2.2 Agricultural Element of County General Plans

California state agencies have expressed concern over the loss of prime agricultural lands through the pressures of urbanization. Economic development and environmental considerations greatly influence the future of agriculture. Because of these concerns and issues the state Office of Planning and Research is cooperating with the County of San Bernardino in conducting a pilot study to seek solutions to local agricultural land-use problems. The results of the study will be included as an element in the county General Plan and will hopefully serve as a model to the other counties within the state.

The goal of San Bernardino County is to prepare and adopt an agricultural element of the General Plan which will assist in assuring the continuing viability of agriculture within the county. The agricultural element will examine the present and future alternatives of this vital activity in relation to growth pressures, economic base and environmental problems.

San Bernardino County is the largest county in the United States and supports considerable agriculture within its 200,000 square miles of land. Agriculture is the single most important industry in San Bernardino County. In recent years, urbanization pressures have reduced agricultural crop production in the county much as in Los Angeles, Orange, and Ventura counties. No longer is the county the leading agricultural district in citrus and wine grapes as it was as recently as 1974. Two hundred acres of citrus were converted to urban land in 1975; in 1976 over 900 acres were urbanized; and in 1977 over 3000 acres have already changed from citrus to houses. The land use trends in San Bernardino County are characteristic of the entire southern California region. Land exists in productive agricultural acreage. As the urbanized area expands, farms and dairies relocate to the periphery of the metropolitan area. Then the cycle begins again, each time with the irretrievable loss of prime agricultural land, open space, and other environmental amenities. The history of the dairy industry, now centered in Chino Valley, (western San Bernardino County, adjacent to the Los Angeles Metropolitan area), is a relevant example of this process. Initially located in Cerritos, dairies migrated to

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La Mirada, and thence to Chino Valley. Now Chino Valley is experiencing urban encroachment pressures and the dairy industry is already making overtures to move to Tulare in the California Central Valley. The citrus industry is experiencing a similar dislocation.

The scope of the project being conducted by San Bernardino County includes 14 tasks, four of which can best/or only be done by remote sensing. The other ten tasks which involve much archival research can best be accomplished by county planners most familiar with planning and development areas.

The four remote sensing tasks with which this grant can be most helpful to both San Bernardino County and the other counties of the state when they become involved are:

1. Develop a system using Landsat imagery that will delineate the urban/agricultural interface and assist in identifying dynamic areas for closer periodic inspection.
2. Assist the county in training personnel to conduct a current land use mapping program of specified agricultural crops and activities.
3. Using current and historic imagery develop a technique for mapping the trend of urban growth or incursion into agricultural areas.
4. Develop an agricultural Information System which includes a system to overlay variously mapped parameters which will result in a map of agricultural land use suitability.

Many planning efforts are geared toward growth management, but do not always fully examine the impact of such growth resulting in the loss of large portions of the major industry within the county. In this case the loss is the agricultural industry. The proposed Agricultural Element is intended to allow policies for the future of agriculture to be integrated and made compatible with the goals and objectives of the general plan concept.

4.3 FUTURE STUDIES

4.3.1 Introduction

As we progress further into the selected resource management problems studies, there are indications of many problems that can only be solved by decisions based on remote sensing data. There appears to be a host of other environmental and resource management problems that can be better solved with the aid of remote sensing techniques and data collection devices. We are also finding that some of the potential problems do not lend themselves to be specifically defined in an annual proposal which requires them to endure a long waiting period of up to one year before research can begin. The most successful research on selected resource management problems will be achieved if the research plan includes a provision to provide for one or two undefined "problems of opportunity", in addition to other pre-defined studies.

Keeping in mind the guidelines outlined for this grant and the need for alternate selection of problems during the grant year the proposal will: 1) outline the research plan for the next year; 2) list some sample types of "problems of opportunity" to clarify our intent to select alternate types of problems during the year; 3) elaborate on the previously suggested work with the California Citrus Production Industry; and 4) discuss the progress on current studies in the California Desert.

4.3.1.1. Objectives

The primary objective of this grant is to demonstrate the unique role that remote sensing can play in providing data to solve environmental and resource management problems, and to encourage resource managers to use remote sensing techniques in their resource management decisions.

Within the guidelines of this grant the specific objectives are:

1. Determine from local, county, state, federal, or private industry resource managers within the state of California which of their current problems have the potential of being uniquely solved by use of remote sensing techniques.
2. Encourage cooperation by the selected agency or industry to participate in a remote sensing research project. The cooperation may be in either matching funds and/or close interaction between agency personnel and UCR researchers.
3. Develop the most suitable remote sensing techniques(s) and apply them to the selected resource management problem.
4. Determine to what extent the data made available from remote sensing was used to make the resource management decision(s) resulting from the research project performed by this grant.
5. Assist the cooperating agency or industry in adopting the remote sensing techniques developed to solve their problem

and report on the effectiveness of the transfer of remote sensing technology.

4.3.2 Specified Studies

During the next year we plan to continue the study of selected problems in the California desert which was the initial project of this grant. Close cooperation with the Desert Planning Staff (DPS) of the Riverside office of the Bureau of Land Management will continue. Future emphasis will be on selected problems confined to a limited study area or areas, and away from performing large scale inventories, a responsibility of the DPS. For example, the sand dunes study described in section 4.2 is a thematic type study dealing with seventeen sample areas of the desert which collectively represent a small percentage of the desert. An opposite time study in terms of areal extent is the wilderness area study also described in section 4.2. The wilderness study could conceivably include the entire desert but we are limiting the study to one or two sample regions to develop a model. The model will assist BLM in applying the results and making decisions on opening or closing of wilderness areas. Any further studies for BLM under this grant will be limited to demonstration models.

The study for the California Citrus Production Industry described in section 4.2 will be started during the current grant year and expected to continue for at least a few months into the next grant year. The period of research is being governed by the citrus production cycle as well as the research funding cycle of the industry which is intending to provide matching funds as their cooperating contribution. The intent of the research is to demonstrate how remote sensing can provide more accurate tree census data to use in their Citrus Crop Forecast.

4.3.3 Unspecified Studies

In order to provide for the "problems of opportunity" previously mentioned we are proposing limited flexible funding under this grant. We plan to allocate our grant funds proportionally between the two specified studies indicated above (California Desert and Citrus Crop Forecast) and reserve a small proportion for one or two unspecified problems that may occur during the grant year. The limited funding of the unspecified problems will permit us to participate in the early stages of research planning and development to aid in solving the problems. As the research progresses from the initial planning and research the selected problems may become the defined studies for the following year. The following section outlines some of the "problems of opportunity" that are under consideration.

Several examples of "Problems of Opportunity" have been derived from contacts made by various local government agencies. We are also listing some example studies that have been completed or are near completion that might have become selected problems had they occurred at another time. The examples may help to clarify both the definition of the term "problems of opportunity" as well as the types of selected problems we intend to choose for active participation in the initial stages of development.

4.3.3.1 Agricultural Element of the County General Plans

Both the legislative branch and administrative branch of the State of California are in the initial stages of a policy to require each county in the state to add an agricultural element to its county general plan. The county of San Bernardino in cooperation with the state Office of Planning and Research is conducting a pilot study to develop a model to be followed by all counties in the state. The agricultural staff planner of San Bernardino County has come to us and asked how remote sensing can assist in developing an Agricultural Element of the General Plan. We believe remote sensing techniques can play a major role in the data gathering and analysis. Further investigation is underway.

4.3.3.2 Urban/Chaparral Interface Study

The California Division of Forestry, the City of San Bernardino, the County of San Bernardino, the San Bernardino National Forest Area of the U.S. Forest Service, and the Riverside U.S. Forest Service Fire Laboratory are cooperating in a small selected area urban/chaparral interface study. The research is directed toward the development of a model (that can be used in other similar areas of the U.S.) that will have a predictive capability to indicate the highest potential fire risk areas. The potential for management decisions as a result of this type study are considerable. Because of the steep topography of most urban/chaparral interface areas it is almost essential to use remote sensing to gather the data for the several correlation factors involved in the techniques of the project. If the model developed is successful, it will be used in zoning, controlled burning, vegetation management, and water shed management decisions. In performing this work we will make certain that our efforts do not duplicate those being made in the Mendocino County Brushfield Study by RSRP personnel at U.C. Berkeley.

4.3.3.3 Chaparral Management Program

The U. S. Forest Service (Riverside Forest Fire Laboratory) has asked us to be involved in the preliminary organization of a chaparral management program. The stated program goal is "To develop, test, and demonstrate vegetation management plans and guideline techniques designed to maintain or enhance chaparral vegetation and related ecosystems for the benefit of man and his environment." The plans and techniques will be designed to achieve a mosaic of chaparral and related ecosystems in terms of age and species composition. Contact with the Fire Lab personnel is being maintained to determine specific research tasks. Such tasks as may be evolved will be evaluated with respect to appropriateness for this grant. It is apparent that remote sensing will be an integral part of the techniques developed but premature to state exactly how the tasks may evolve.

4.3.3.4 Problems Recently Solved Using Research Information and Techniques Resulting From Previous NASA Grants

The following two examples are given of recent events that fit the "problems of opportunity" concept. The problems were solved by use of data and techniques under NASA sponsored grants. The examples are indicative of how problems can be solved with research by remote sensing techniques.

4.3.3.4.1 CALTRANS Alternate I-15 Freeway Socio-Economic Cost Benefit Study

In this example of selected problems, research has occurred for which we already had the data available from our previous NASA work. The State Department of Transportation (CALTRANS) recently asked for assistance in gathering data in western Riverside county for a cost-benefit study of alternate freeway routing based upon the socio-economic impact in the predominately rural area (e.g. horse ranches, dairy industry, recreational sites). Having completed a remote sensing data based study of the area in the past year we were able to provide the land use data, complete with areal statistics, which CALTRANS has promptly employed in their study. The land use data provided by remote sensing will be used in the final decision of alternate route selection.

4.3.3.4.2 Geothermal Element of the Imperial County General Plan

Another resource management decision problem we have recently completed on another grant that is pertinent to this discussion was conducted in Imperial Valley, California. The county supervisors were required to establish a geothermal element to their county General Plan. The contribution of remote sensing to the larger study (which included extent of geothermal resources, economic, social, and political impact, etc.) was to provide a general estimated crop value for each field. The problem was that the fields were rotated two or three times a year between as many as eight crops in four years. An average crop value was established using Landsat I and II imagery and U-2 high altitude aircraft imagery sampled over a period of eight years. Placed into a geographic data base the system is being used by the economists to establish the impact if certain agricultural fields are lost to geothermal production and/or damage (i.e. subsidence of the ground).

4.4 TECHNOLOGY TRANSFER OF LAND USE MAPPING TECHNIQUES UTILIZING REMOTE SENSING

Our water demand studies of the Upper Santa Ana River Drainage Basin led us to develop rapid means of land use mapping using remote sensing as a data source. The techniques involve photo manipulations for data transfer from the image and computer manipulations for data storage, retrieval, and map reproduction. The study area is comprised of 1.5 million acres which is a typical problem for the government agencies in the state.

During the last four years under this study we were in contact with the state Department of Water Resources (DWR) personnel as well as the local county agencies. All the agencies showed interest during the project, but maintained a skeptical attitude about their ability to adopt the new techniques due to the barriers imposed by the government bureaucracy. Much to our surprise and pleasure we received three requests from state and local government agencies this past summer to adopt our system or use our data system; the results are attested to by the appended letters.

The biggest surprise was the adoption of our automated land use mapping techniques by the state Department of Water Resources (DWR) to include the transfer of all relevant computer programs. For four years the DWR had stated that they would not be able to obtain a budget for the adoption of the techniques, but agreed with the method. Perhaps the major selling point was the ability of the automated system to calculate the complete land use areas by acres from a map in a few seconds. DWR has long used remote sensing as a data source but was measuring land use areas by cutting each land use type out of the map (like paper dolls) and then weighing the cut-out areas to determine the percent of each land use type compared to the weight of the paper of the entire map. We feel the statewide adoption by DWR of the entire remote sensing and automated mapping system developed at UCR with NASA support is a step forward and an acceptance for which we can take pride.

The two other agencies, Riverside County Planning Department, and the state Division of Highways (California Transportation Agency - CALTRANS), had an immediate requirement for updated land use maps for planning purposes. The areas involved would have required each agency to spend tens of thousands of dollars to obtain the data by conventional means. Our system was able to provide the data immediately and save considerable money for both agencies. They both agreed that the state should have a central agency providing land use data from remote sensing of the environment in a machine reproducible form. CALTRANS required the computation of land use areas by type and individual land use area and were not able to obtain the data from any other source. The CALTRANS requirements were for data to assist in writing an Environment Impact Report for a section of a new freeway (I-15W) in the west end of the Santa Ana River Basin.

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APPENDIX

DEPARTMENT OF WATER RESOURCES

P.O. BOX 388
SACRAMENTO
95802

(916) 445-2296



August 9, 1977

Dr. Leonard Bowden
University of California
at Riverside
Riverside, CA 92521

Dear Dr. Bowden:

I wish to express my appreciation for the material provided to the Department of Water Resources by Mr. Dave Nichols of your staff. This material consisting of computer programs to edit and process digitized data and the resultant maps is aiding us in our study to upgrade our present land use mapping activities.

Of particular help are the time and cost figures provided as this information is vital in determining costs vs. benefits when selecting new methods. The various computer drawn maps have shown our Mapping Division personnel the state-of-the-art in automated mapping, allowing them to assess the value from this type of processing.

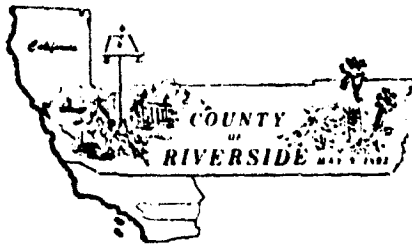
Taking advantage of Mr. Nichols' expertise in the subject has greatly reduced the amount of time we would have had to spend investigating the area of computer mapping. The programs he has provided will allow us to investigate numerous alternative processing methods and not rely so heavily on vendor supplied software and hardware exclusively. In this age of limited funds for experimentation it is quite an advantage for this department to have available from the University products which are directly applicable to our needs.

Thank you again, and I hope we can continue to work with you and Mr. Nichols as we implement these new procedures in the Department.

Sincerely,


Charles W. Farrell, Chief
Computer Systems Office

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RIVERSIDE COUNTY PLANNING DEPARTMENT

PLANNING COMMISSION

ELMER M. KATZENSTEIN, Chairman, Rubidoux

KAY S. CENICEROS, Hemet
JESS E. LILLIBRIDGE, Corona
KAY H. OLESEN, Palm Desert

JOHN H. WAGNER, Cherry Valley
RUSSELL E. CAMPBELL, Blythe
MARION V. ASHLEY, Perris

CAM:72259

July 11, 1977

A. E. NEWCOMB - PLANNING DIRECTOR

4080 LEMON STREET, 9th FLOOR, RIVERSIDE, CALIFORNIA 92501
TELEPHONE (714) 787-6181

Dr. Leonard W. Bowden
Earth Sciences Department
University of California
Riverside, CA 92521

SUBJECT: Utilization of UCR Land Use
Data in 208 Wastewater Manage-
ment Planning Program

Dear Doctor Bowden:

Recently, this Department completed a land use study in partial fulfillment of a contract with the Southern California Association of Governments (SCAG) to help develop a 208 Wastewater Management Plan for the Santa Ana River Basin.

The subject land use study was actually a composite of several recent, independently-developed studies. The purpose of the project was to provide current land use data which could be utilized to calculate pollutant loadings from agricultural and urban sources, and to assess the adequacy of baseline data used in the SCAG '76 land use forecast.

During the data gathering stage of the project, it was discovered that some of the land use data which we had planned to use was unavailable to us. We then contacted your Remote Sensing Lab to see if any data might be available to us. Fortunately, we learned that your Department had completed a land use study in 1975-76 which was very suitable to our needs and which could be made available to us. Thanks to the excellent assistance of Mr. Dave Nichols of your staff, we were able to secure and utilize your land use data in the preparation of our land use maps and acreage tabulations.

I would like to point out that we found the quality and utility of your data to be excellent. The computerized mapping format blended extremely well with the other data that we were using, and the land use classifications were very compatible to ours. I should like to add that the utilization of your data probably saved our agency (and, ultimately, the taxpayers) a considerable amount of money; for example, in 1974, the County of Riverside paid roughly \$35,000 for a very similar land use study encompassing approximately 800 square miles.

Dr. Leonard W. Bowden
July 11, 1977
Page -2-

I would like to take this opportunity to thank you and your staff for their cooperation and assistance during our project. If we can be of any assistance to your Department in the future, please give us the chance to return the favor.

Very truly yours,

RIVERSIDE COUNTY PLANNING DEPARTMENT


A. E. Newcomb - Planning Director

AFN:dla

cc: Supervisor Record
Supervisor Younglove

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DEPARTMENT OF TRANSPORTATION

DISTRICT 8, P. O. BOX 231

SAN BERNARDINO, CALIFORNIA 92403



August 12, 1977

08201-186001
Magnolia Ave to
Route 60

Mr. Claude Johnson
Earth Sciences Department
Geography Research Department
University of California
at Riverside
900 University Avenue
Riverside, CA 92507

Dear Mr. Johnson:

Thank you for your aid in obtaining information to be used in the preparation of an Environmental Impact Statement for Interstate Route 15 through the Corona-Norco area.

The land use information received from the maps and tabulations included in the NASA-UCR study has proved invaluable in determining various land use types located in the Norco Reach Study Area. The data was especially helpful in delimiting agricultural acreages. Also the data was used in correlating information received from other agencies.

Your help and cooperation in obtaining the data requested is appreciated.

Very truly yours,

J. E. PEDDY
District Director

By *C. N. Smothers*
C. N. Smothers
Environmental Planner



United States Department of the Interior

IN REPLY REFER TO

1120
(C-961.4)

BUREAU OF LAND MANAGEMENT
California Desert Plan Program
1695 Spruce
Riverside, California 92507

SEP 12 1977

Dr. Leonard W. Boden
Dept. of Earth Sciences
University of California
Riverside, CA 92507

Dear Dr. Boden:

John Milhauer has discussed with me your work in remote sensing related to the NASA Selected Problems Grant. We are most interested in whatever efforts can be directed toward assisting us in our identification of roads and intrusions in the California Desert. To our knowledge, no precise methodology has been developed for photo interpretation and classification of unimproved roads and jeep trails in desert environments. This information is critical to our desert-wide planning effort since Congress has mandated that we complete wilderness evaluations; the presence or absence of roads -- however they are ultimately defined -- will be crucial factors in evaluations of wilderness study areas.

The Bureau of Land Management must inventory some 16 million acres of desert land in the next year and half in order to fulfill the requirements of the Federal Land Policy and Management Act of 1976. On-the-ground identification and classification of roads, as you can imagine, would be a major endeavor. We see the NASA Selected Problems Grant as an opportunity for substantial assistance in our work while providing a vehicle for new remote sensing applications development. Wildland value determination is an increasingly important issue in land use planning nationally. Our desert study should provide for development of methodologies with potential applicability in other areas.

We look forward to your possible assistance and the opportunity to work with you.

Sincerely yours,

Robert Badaracco
Lead Outdoor Recr. Planner

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SPECIAL STUDY NO. 1

REMOTE SENSING AS AN AID TO
WILDLIFE HABITAT IDENTIFICATION
IN MENDOCINO COUNTY, CALIFORNIA

Note: This preliminary report pertains to Landsat-based work on habitat mapping that our RSRP personnel propose to do in essentially the same geographic area as that in which our on-going work on fuel mapping is taking place. A comparison of this "Special Study" report with the "Fuel Mapping" report of Chapter 2 will clearly show the excellent possibility for making these two studies complementary rather than duplicative.

SPECIAL STUDY NO. 1

Remote Sensing As An Aid To Wildlife Habitat Identification In Mendocino County, California

by

Edwin F. Katibah

Remote Sensing Research Program, Berkeley Campus

INTRODUCTION

Mendocino County is an area of tremendously varied vegetation/terrain communities and consequently it has the ability to support a large variety of game and non-game animals. Of particular interest to Mendocino County and the California Department of Fish and Game is the identification of various kinds of upland game habitat, including those kinds which can support wild turkey populations.

Wild turkeys, never native to California, were first introduced here in 1877 by ranchers on Santa Cruz Island. The California Department of Fish and Game began a stocking program in 1908 when 22 birds were released in Southern California (Harper, 1977). Since then, thousands of turkeys have been released by the Department throughout California.

Two major problems currently exist in the wild turkey stocking program. First is the difficulty in obtaining birds for transplanting. Some birds are captured within the state from existing populations, while others are received from out-of-state. This leads into the second problem, namely that of determining the location of suitable habitat in which to transplant these birds. Turkeys captured from within the state as well as the majority of those received from out-of-state are generally from one of three races known, respectively, as the California Hybrid, Mirriams, and Rio Grande. While each race of turkey has the same general habitat requirements, each either needs, or can tolerate, different specific habitat requirements or preferences.

APPROACH

As the result of a preliminary meeting which personnel of our Remote Sensing Research Program held with California Department of Fish and Game biologists in Covelo, Mendocino County on November 2 and 3, 1977, it was considered as highly probable that remote sensing data analysis techniques could, indeed, be used successfully in identifying suitable wild turkey habitat.

The California Department of Fish and Game indicated that it would not only be willing to cooperate in our remote sensing-based study, but would, if the study indicated specific sites that were better wild turkey habitat than sites already known to exist in Mendocino County, be willing to transplant wild turkeys into such sites.

It was agreed that Landsat II digital data would be the appropriate basic information source. Through use of the spectral response information from the four Landsat MSS channels, a basic masked and stratified supervised classification of Landsat imagery could be obtained, with good prospect that it would identify the oak/grass/conifer vegetation mix that constitutes good wild turkey habitat. With specific reference to our proposed study area in Mendocino County, this possibility is clearly indicated for example, in Figure 3a of Chapter 2 of this progress report. In fact the presently proposed wildlife habitat study, covering as it does essentially the same test area as our fuel mapping study of Chapter 2, could be considered as complementary to it in all respects.

Refinement to the classification procedure used in this basic habitat classification could be introduced through data masking and stratification. The masking would allow only those gross areas of Mendocino County which have the basic ingredients of good habitat to be classified. For instance areas in the Coastal Redwood Zone presumably could be eliminated immediately and not classified. The stratification would be done in such a way as to allow the introduction of ancillary information such as mean monthly/annual rainfall, soil type, and mean monthly/annual temperature. Using an analysis technique such as this should help to locate specific areas satisfying the habitat requirements of one or another of the three major wild turkey races used in California.

PROPOSED WORK TO BE PERFORMED IN 1978

On December 12, 13 and 14, 1977, RSRP scientists will again meet with California Department of Fish and Game biologists in Ukiah, Mendocino County. During those three days, RSRP personnel will participate in trapping wild turkeys for transplanting in adjacent, previously selected areas. It is anticipated that the final details regarding the Department's cooperation and information needs will be established at that time. Early in 1978, the Department will cooperate by helping to establish the specific habitat criteria for each of the three wild turkey races. Furthermore, small training areas will be delineated in sites of known turkey habitat by Department personnel.

It is proposed that, in conjunction with these efforts, RSRP scientists proceed to develop the specific analysis model to be used for the final habitat classification from Landsat data. In addition the approximate dates will need to be established during which, in any given year, the vegetation exhibits a seasonal appearance that best lends itself to classification, as imaged by Landsat. Once this has been done, the appropriate Landsat digital tapes, and other ancillary data can be ordered and the appropriate turkey habitat classifications made.

The figures which follow will do much to show both the possibilities and limitations associated with attempts to use remote sensing as an aid to the selection of suitable sites in which to transplant wild turkeys. All of the aerial photos appearing in those figures show area that are within our test site in the northeastern part of Mendocino County. They were taken jointly by personnel of the RSRP and the Department on November 2, 1977.

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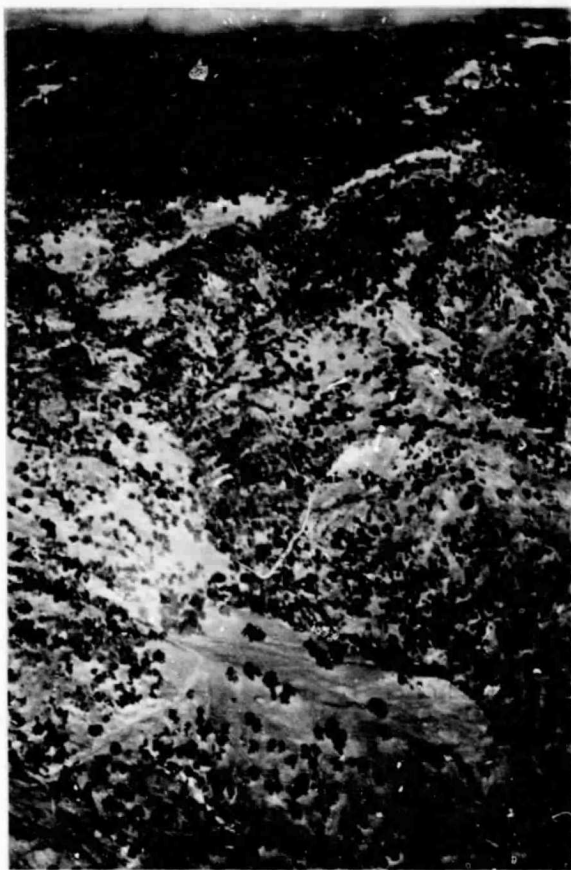


Figure 1. This infrared color aerial photo shows an area near Covelo that has most of the following attributes of a good wild turkey habitat: (a) predominantly an oak-grassland vegetation cover for a contiguous area of 5000 acres or more; (b) a few tall coniferous trees in which the birds can perch; and (c) considerable distances from farmyards to which the wild turkeys might readily migrate and become domesticated.

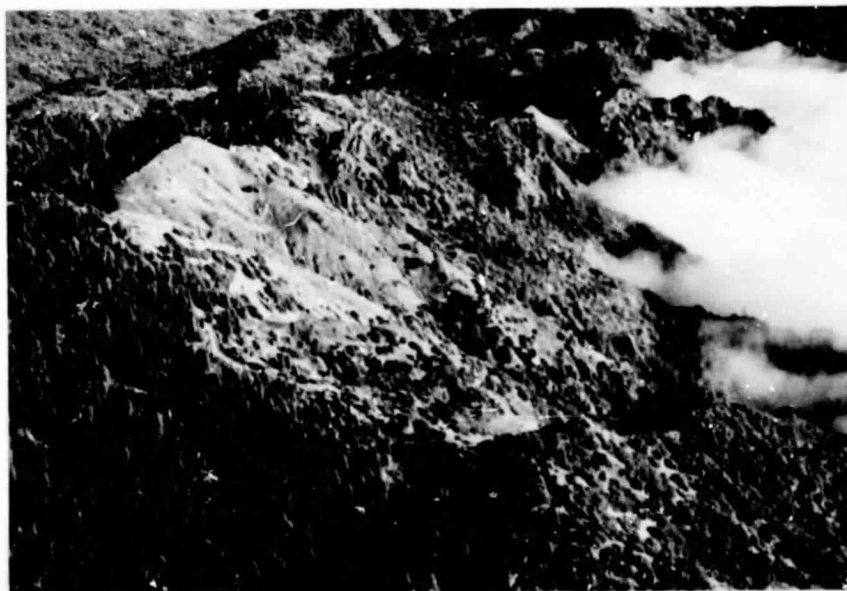


Figure 2. A higher elevation area, of less accessibility, but also less suitable for wild turkeys in terms of vegetation cover is shown in this infrared color aerial photo.



Figure 3. Remote sensing confirms that the areas shown in these two photos possess the attributes of a good turkey habitat as listed in the caption to Figure 1. Consistent with that analysis, successful turkey transplants were made in both of these areas a short time ago. The remote sensing expert therefore can use these two photos with confidence (as reference images or "keys") as he seeks to select additional turkey transplant sites.



Figure 4. Shown on this aerial photo stereogram is an area immediately to the north of Round Valley in Mendocino County. Most of the land seen in this photo is within an Indian Reservation. This area, like the ones in Figures 1 and 2, is seen to have the attributes of a good site in which to transplant wild turkeys. In addition it is a very favorable winter range for deer that migrate to these lower elevations from the surrounding mountains. Consistent with the latter observation, on November 3, 1977, RSRP personnel counted 58 deer from a single vantage point within the area shown here.

SPECIAL STUDY NO. 2
REMOTE SENSING OF DIPTERAN BREEDING HABITATS

Note: The special study discussed in this report is being initiated, with NASA approval, as a joint effort between the Remote Sensing Research Program of the University of California and the Lake County Mosquito Abatement District (LCMAU). As will be apparent from this report, LCMAU personnel are providing the rationale, technical guidance, and matching efforts by field crews, all of which are necessary for the successful conduct of the study. Personnel of the University's Remote Sensing Research Program at Berkeley are providing, initially, the expertise needed for adequately interpreting remote sensing imagery. They are doing so, however, with a view to transferring this technology to the user agency (i.e., LCMAU) as promptly as possible so that, in the near future, that agency will be able to employ these techniques routinely, economically, and on a self-sustaining basis.

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SPECIAL STUDY NO. 2
Remote Sensing of Dipteran Breeding Habitats

by

Arthur E. Colwell
Director of Research, Lake County Mosquito Abatement District

INTRODUCTION

The locating of larval habitats is an important step in controlling pestiferous dipterans. Aquatic habitats are the important sources of larvae of many such insects. In Lake County, California, dipterans in the families Chaoboridae, Chironomidae, Culicidae, and Ceratopogonidae are the most important pests and all breed in lentic (standing water) habitats. Construction or termination of agricultural or recreational ponds or irrigated pastureland, as well as changes in the volume of natural standing waters, pose needs for at least annual assessment of potential larval breeding sources (Whitworth 1976). When ground crews locate the potential sources, those bodies of water which support a large population of pest species can be modified by source reduction or by the application of appropriate biological or chemical control agents (Apperson et. al. 1976; Cook 1965, Mulla 1976). When field checking indicates that a source which appears to provide favorable larval habitat is not producing a dipteran problem, further studies may be initiated to determine what biotic or abiotic factors may be controlling the larvae, and whether these factors might be propagated in order to control the larvae in other areas.

RATIONALE FOR THE STUDY

The development of a remote sensing-based capability for locating and monitoring areas in Lake County that serve as breeding sources of pestiferous insects is of particular importance because of the following combination of factors:

1. Lake County is a primary recreational area for the millions of people living in such nearby localities as the San Francisco Bay Area and the Great Central Valley of California.

2. As a result, in favorable years the revenue to Lake County from tourism and recreation exceeds \$15 million per year, an amount which is second only to the income that is derived from the county's agricultural industry.

3. By far the most serious deterrent to recreational use in Lake County is the presence of mosquitoes, biting gnats, midges, and other pestiferous insects (McClusky 1976).

4. The populations of these insects fluctuate widely from year to year, and from one part of the county to another, depending in part upon fluctuations in the lakes, ponds and other aquatic habitats that serve as breeding grounds for the insects.

5. Effective control of these insects often is possible through timely treatment of their aquatic breeding grounds (Apperson et al. 1976, Cook 1967).

6. Consequently, there is a need for periodically obtaining accurate information regarding the location and condition of each such area and also regarding the most suitable route for use in driving and/or walking to it.

7. As indicated by the photographic illustrations appearing later in this report, the use of modern remote sensing technology offers a greatly improved means, with respect to any means that was previously available, for acquiring this information.

SOME DETAILED CONSIDERATIONS WITH RESPECT TO THE STUDY AREA

Shallow water areas which are protected from wave action, and which can be important mosquito breeding sources, are common in Lake County. These include some irrigated pasturelands and marshy wetlands. Some natural vernal pools may also produce mosquitoes at times. Frequent remote sensing of potential shallow-water areas may indicate which sources contain water (active sources) and which have no water. Knowledge that a pool has dried up may be particularly important, since predators, especially mosquitofish (Gambusia affinis) may have been eliminated. In such instances, mosquitofish should be replanted in these areas when water returns.

In deep water areas which are subject to some currents and wave action, other dipterous pests are important. The Black Biting gnat (Culicoides

variipennis), a vector of bluetongue virus (Luedke et al. 1977) has been found in waters up to 3 meters deep in Lake County (Apperson 1975). The Clear Lake gnat (Chaoborus astictopus) and several species of chironomid midges (e.g., Chironomus plumosus) are extremely important pests inhabiting water bodies at depths up to 25 meters (Hazeltine 1963, Herms 1937). Most natural deep bodies of water in Lake County have been identified, but the number and location of artificial impoundments is subject to change.

From a remote sensing standpoint, there appear to be two major types of artificial impoundments. One type is characterized by the presence of a dam or levee which normally retards the flow of a stream or other water-course. The shape of these impoundments, as seen on aerial photography, will often be somewhat triangular, although other shapes are possible due to convergent drainage systems and other topographic features. The surface area covered by such an impoundment may change drastically in aerial imagery taken at different times. Also the depth of the water and hence the optical density of the image may vary considerably among images taken at different times. The optical density of the image may also be affected by the amount of turbid runoff water which has entered the impoundment, and in the case of larger bodies of water by the degree to which wind action has increased the turbidity of the waters.

The second type of artificial impoundment is created by excavating a large hole in the ground. The hole is then filled with water from a spring or well. The ponds created in this manner are commonly rectangular in shape. Usually these ponds are not dependent upon surface runoff and are not necessarily located in stream channels. The excavated ponds are usually less than 1 acre in size, whereas the levee-formed ponds may be much larger. The surface area and depth of the excavated ponds may not fluctuate drastically during wet or dry weather periods. Also the amount of turbidity and reflectance of light (as indicated by the optical density of the aerial imagery) does not vary greatly in these ponds since they are not filled by runoff water and usually are not large enough (have insufficient fetch) to be subjected to substantial overturning of bottom sediments due to wind-produced currents.

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DESCRIPTION OF PRELIMINARY INVESTIGATIONS AND FINDINGS

On each of 3 different dates (August 9, November 4, and November 17, 1977); personnel of the University's Remote Sensing Research Program accompanied the present writer to various sites in Lake County, including those appearing in Figures 1 through 9 of this report. The primary objective was to locate sites in Lake County within which to conduct tests relative to the remote sensing of dipteran breeding sources.

Three types of remote sensing imagery were used:

(1) a Landsat color composite (simulated infrared color photograph) made from digital data acquired on 3 February, 1974 in the green, red and near-infrared bands (bands 4, 5 and 7) through use of Landsat's multispectral scanner. For use in the present tests the color composite was enlarged to a scale of 1/250,000 (See Figure 2);

(2) High-flight photography taken with infrared color film by a U-2 aircraft from an altitude of 65,000 feet at a scale of 1/130,000, on 2 dates, April 6, 1973 and August 9, 1974. (See, for example, Figures 3 and 4); and

(3) Conventional black-and-white aerial photography taken with the usual "panchromatic minus-blue" film-filter combination, at a scale of 1/20,000 and enlarged to a scale of 1/5,000. (See for example Figure 5).

From a study of these 3 types of imagery a few representative areas were selected for investigation in the field. In each instance, from a study of the 2 larger scales of imagery, the most suitable route was chosen for travelling by vehicle to the immediate vicinity of the selected area. In addition, the most suitable route was selected for travelling by foot from the point where the vehicle was to be parked to each of the lakes, ponds, or other features that were to be field checked.

With the aid of the annotated imagery each site was then visited, field checked in terms of its significance as a dipteran breeding source, and photographed with conventional color film. (Representative terrestrial photos taken in the field appear in Figures 6 through 9.)

CONCLUSION

As indicated by the captions which accompany the photos that appear in this report, the 3 types of remote sensing imagery that were tested already have proven to be very useful in each of the following 3 ways: (1) in locating lakes, ponds, and other dipteran breeding sources; (2) in estimating conditions that exist there; and (3) in determining the most suitable route for walking and/or driving to each such area. Consequently it is proposed that a more complete feasibility study be conducted in Lake County during calendar year 1978.

With a view to maximizing the operational usefulness of remote sensing technology for the various previously-stated purposes, an effort would be made in this future study to develop remote sensing aids known as "Procedural Manuals". This effort, like all other aspects of the study would be undertaken jointly by personnel of the Lake County Mosquito Abatement District and those of the Remote Sensing Research Program of the University of California. It would be the intent to include in these manuals the step-by-step procedure that one should follow when seeking to maximize the usefulness of remote sensing imagery as an aid to the location and appraisal of dipteran breeding areas, whether those areas are in Lake County or in any other analagous part of the world.

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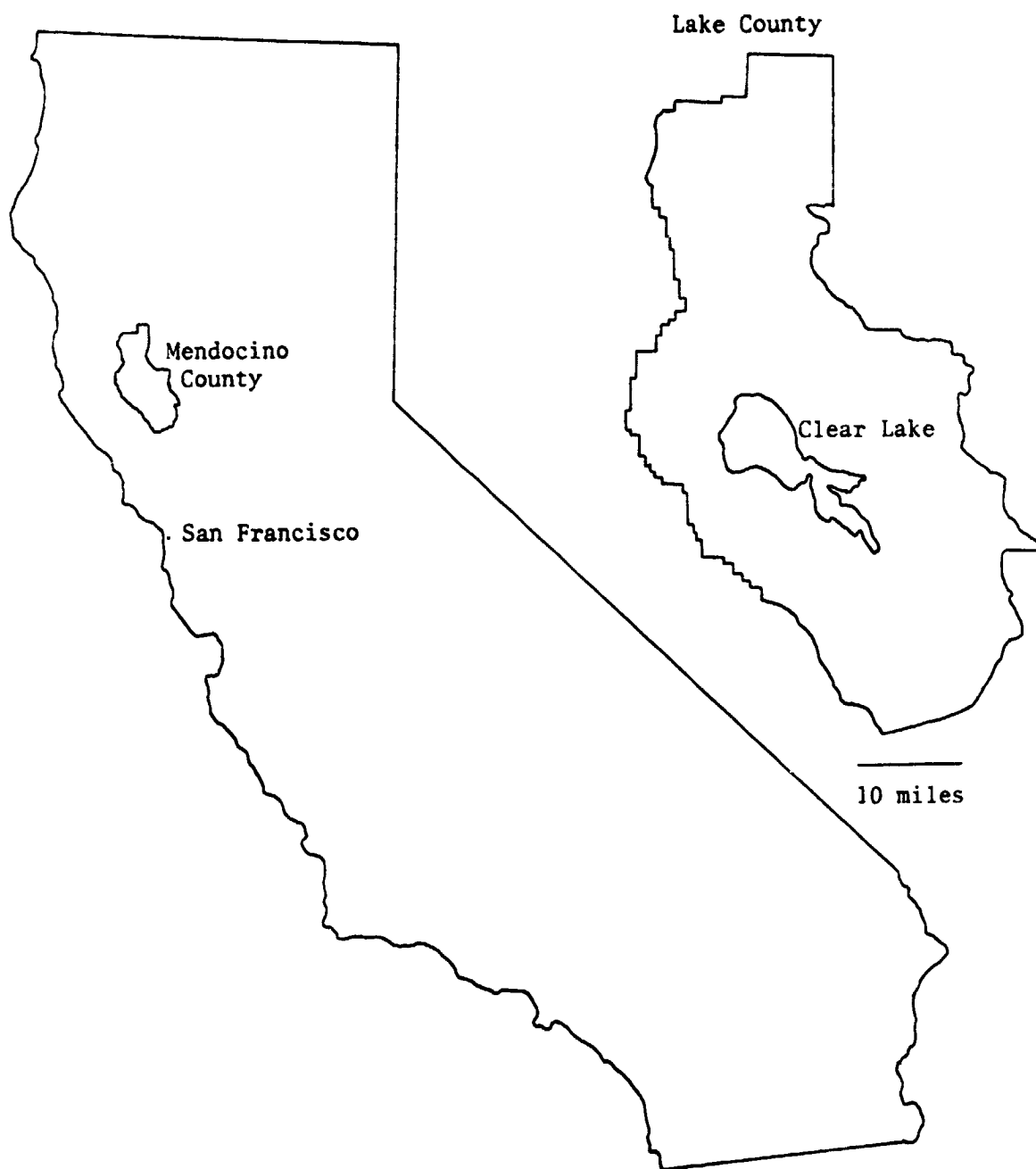


Figure 1. Map showing location of the Clear Lake Test Site in which experiments on the remote sensing of dipteran breeding sources are being conducted.



Figure 2. Landsat color composite imagery of clear lake and its environs, scale 1:150,000.

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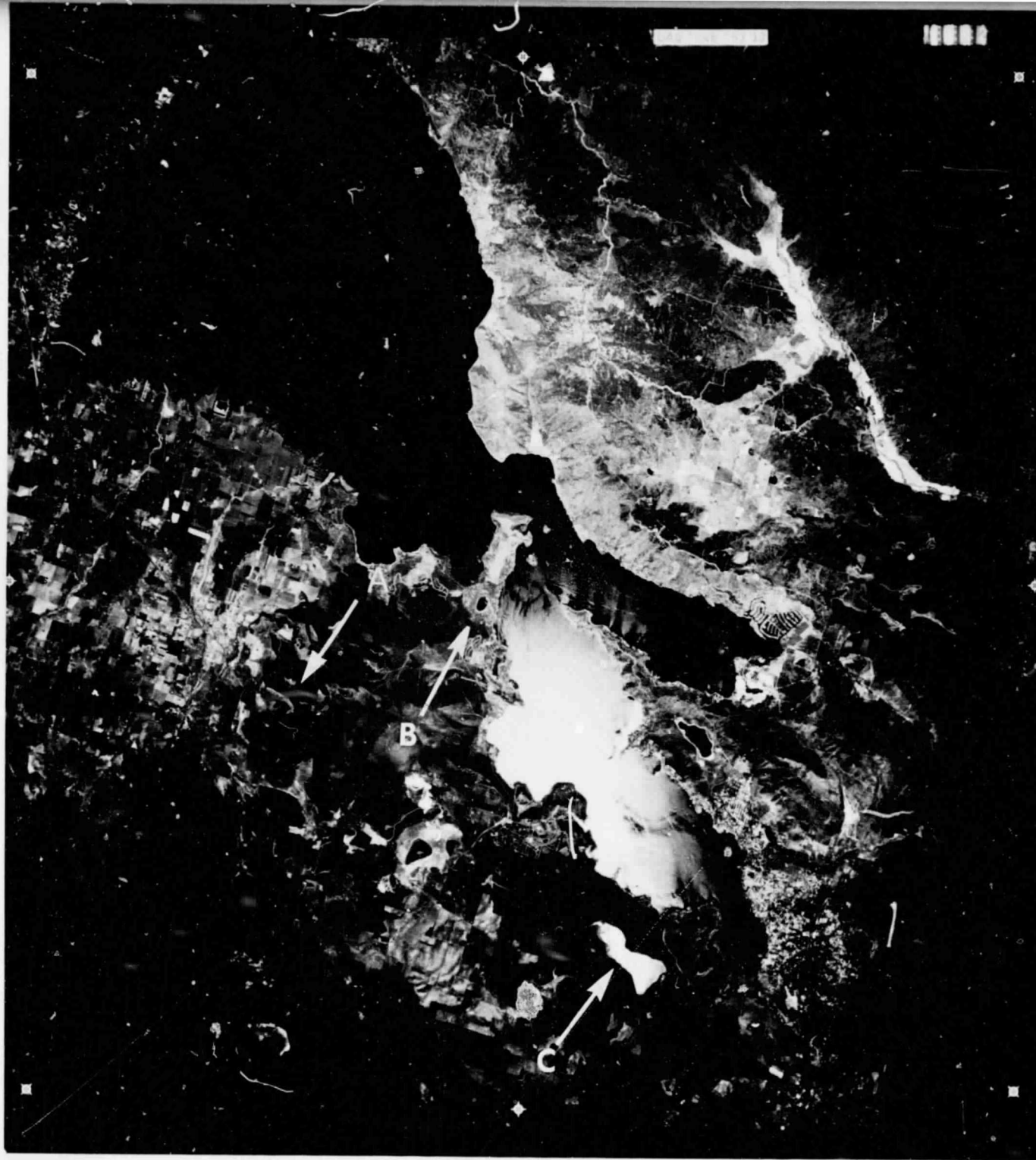


Figure 3. Infrared color aerial photo taken from an altitude of 65,000 feet of the test area in Lake County, California, on August 14, 1974. The photo scale as seen here is approximately 1/125,000. Most of Clear Lake (the largest natural lake that is entirely within the state of California) appears in this one photograph. Areas A, B and C, the 3 rectangular areas that have been delineated on this photograph, are shown at larger scale in Figures 4A, B and C, respectively.



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Figure 4A. Stereogram showing a 3-diameter enlargement of area A as labelled in Figure 3. Compare with the larger scale aerial photo of Figure 5 and with the terrestrial photos of Figures 6 and 7.

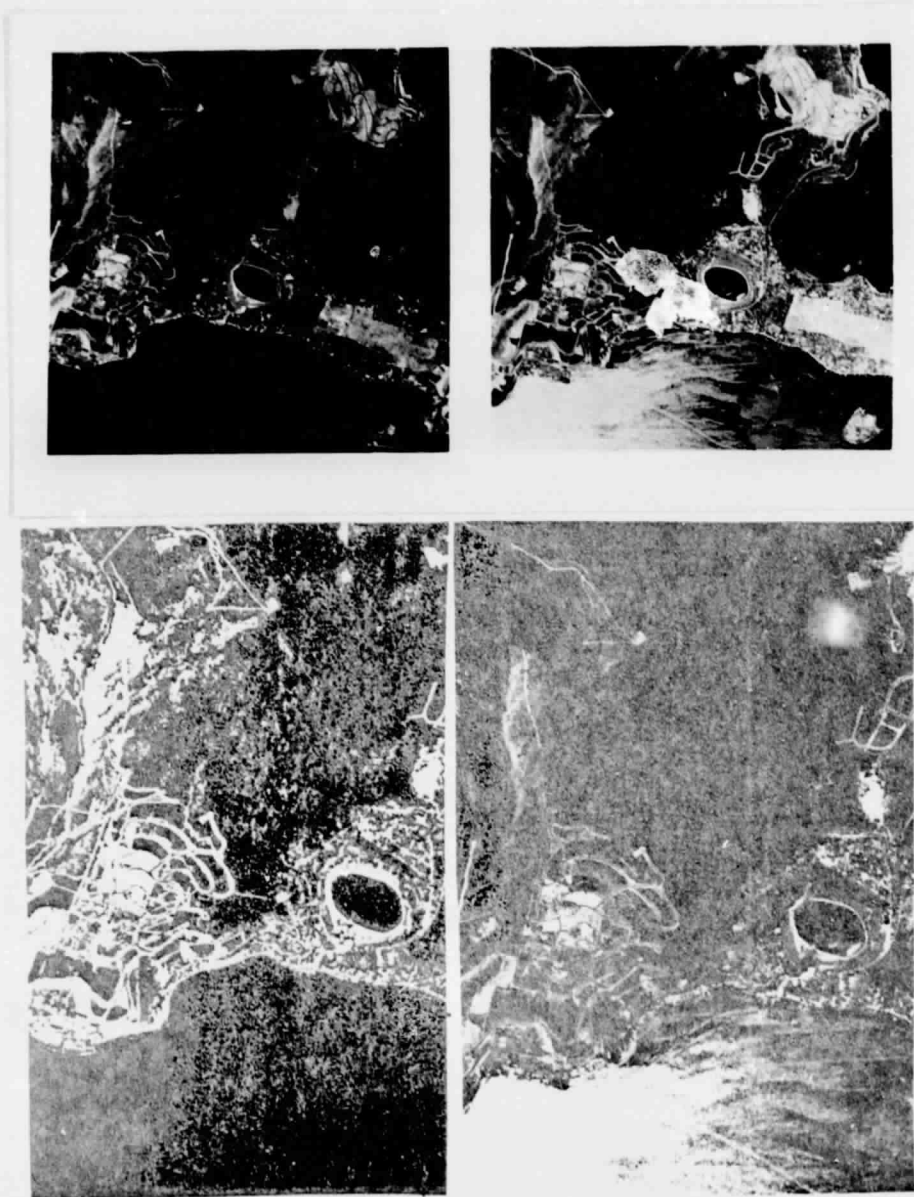


Figure 4B. Stereogram showing a 3-diameter enlargement of area B as labelled in Figure 3.

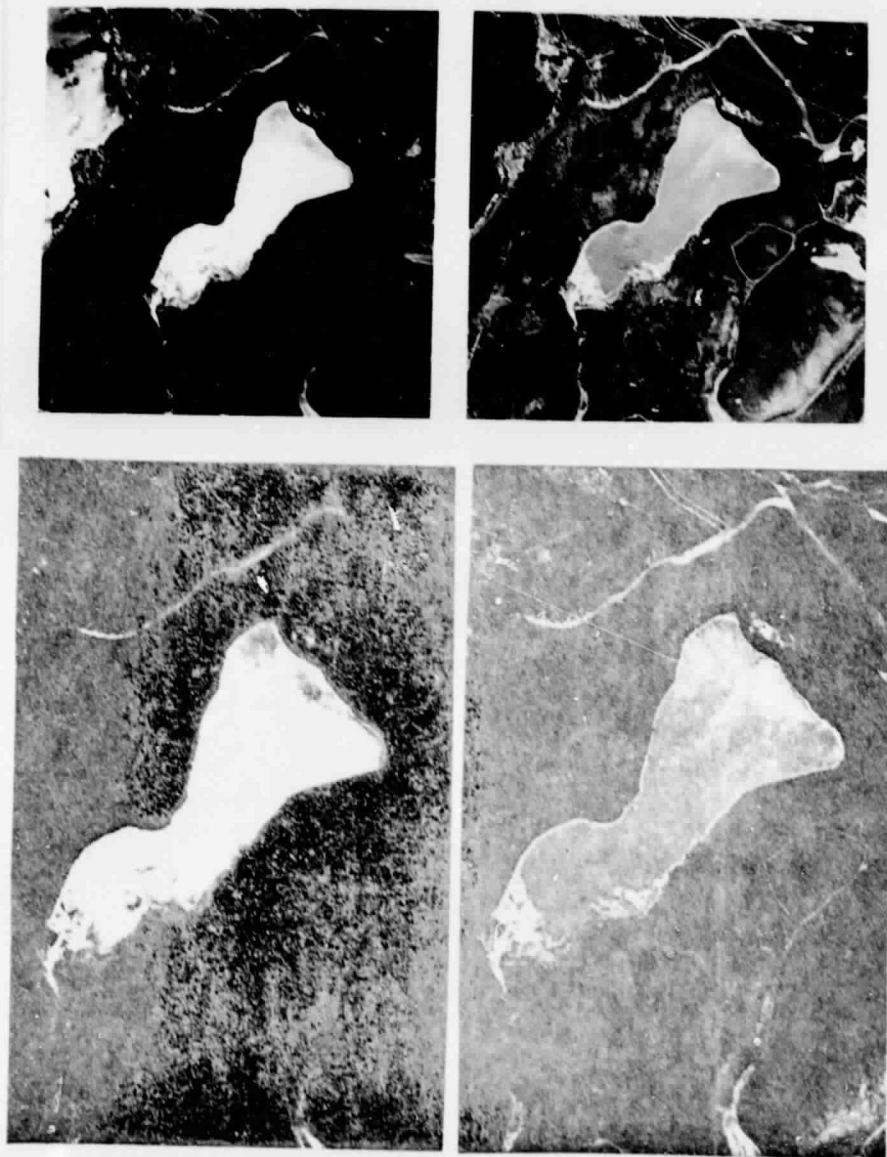


Figure 4C. Stereogram showing a 3-diameter enlargement of area C as labelled in Figure 3.

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Figure 5. Vertical aerial photo of most of area A, as labelled on Figure 3. This photograph was taken with panchromatic film and a minus blue filter at a scale of 1/20,000 on July 3, 1952. It is shown here, enlarged to a scale of approximately 1/5,000. The arrows that have been annotated on this photograph show the locations and camera orientations used in taking the correspondingly-labelled terrestrial photos of Figures 6 and 7.

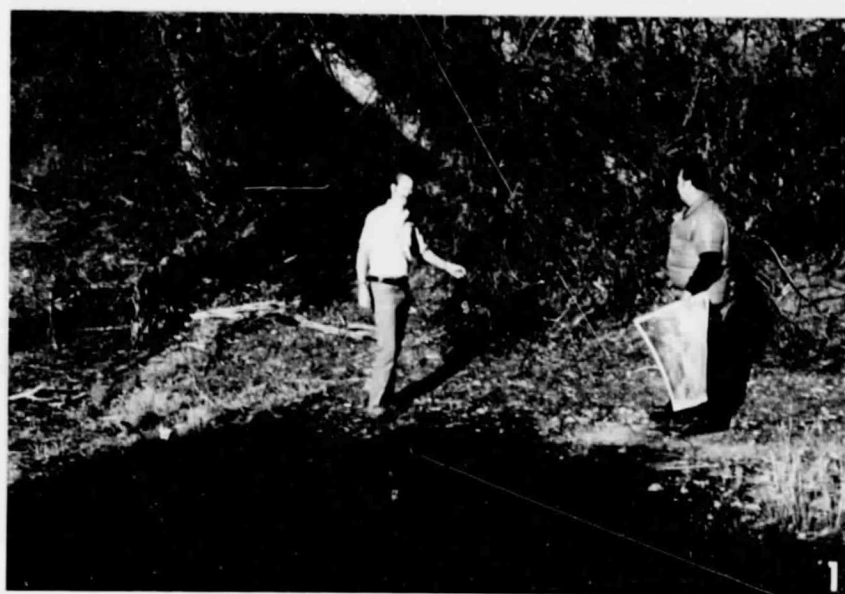


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Figure 6. Terrestrial photos taken on November 4, 1977. See arrows on Figure 5 which indicated the locations and camera orientations used in taking these correspondingly-labelled terrestrial photos. Note that, on this date the lakes shown were dry, but that in 1974 (as seen in Figure 4A), they contained water.



Figure 7A. Terrestrial photos taken on November 4, 1977. See Arrows on Figure 5 which indicate the locations and camera orientations used in taking these correspondingly-labelled photos. Photos show levee-formed artificial impoundments which were created by erecting small dams across stream beds.



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Figure 7B. These two photographs are of the reservoir that is located at the area labelled "H" in Figure 5. In both of the above photographs the same type of potential problem in relation to mosquito and gnat abatement exists. Specifically, when the areas shown here are flooded (due to the filling of the reservoir during the rainy season), the dead branches create still-water conditions that are unusually favorable for the breeding of aquatic insects. The possibility of detecting such conditions by means of remote sensing currently is being investigated.



Figure 8. Terrestrial photo taken on November 17, 1977 of area shown in the color infrared stereogram of Figure 4B. Arrow appearing on that stereogram indicates point from which the above corresponding numbered photo was taken and the camera orientation that was used. Note that a lake of this expanse and depth was not even approaching dryness in 1977, when this terrestrial photo was taken. This lake is sometimes a breeding source for Anopheles franciscanns mosquitoes and Paralauterborniella elachista midges.

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Figure 9. Terrestrial photo taken on November 21, 1977, during field studies of area shown in the color infrared stereogram of Figure 4C. Note that the lighter tone of this lake, as seen here (indicative of higher sediment load), is clearly seen on the high-flight photography of Figure 4C, also. The field studies of this lake indicated the Secchi depth was 16 cm. and the turbidity (measured with a Hach model 1860 nephelometer) was 90 Jackson Turbidity Units (J.T.U.).



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Figure 10. Terrestrial photo of a second type of pond which differs from the type shown in Figures 6 and 7 in these respects: (1) it was dredged out; (2) it is rectangular in shape; and (3) being fed by springs or wells, it's water level remains relatively constant and hence it constitutes a different type of breeding habitat for gnats and mosquitoes.

CHAPTER 6
PROJECT SUMMARY
Robert N. Colwell

Among the natural resources that are of concern to the various resource management groups and agencies in California are timber, forage, soils, water, minerals, agricultural crops, fish, wildlife, and recreational resources. The major objective of this project is to demonstrate, by means of Case Studies, the very significant extent to which information that is derived through the use of modern remote sensing techniques can lead to the development and implementation of more intelligent measures for the management of these Resources than would otherwise be possible.

The three Case Studies that are the primary subjects of the present progress report are:

Case I. "Fuel Mapping in Relation to the Management of Brushlands and Timberlands in Mendocino County, California";

Case II. "Kern County Watershed Runoff Feasibility Study"; and

Case III. "An Integrated Study of the California Desert Using Remote Sensing Techniques".

The following constitutes a brief recapitulation of the more detailed statements appearing earlier in this report under the above three headings (in Chapters 2, 3, and 4) and under related activities.

Case I is being studied primarily by personnel of the Remote Sensing Research Program (RSRP) on the Berkeley campus, in cooperation with a variety of interested agencies in Mendocino County. These include the U.S. Forest Service, the Bureau of Land Management, the Bureau of Indian Affairs, the California Department of Forestry, the California Department of Fish and Game, the Mendocino County Board of Supervisors, the Mendocino County Fuel Control—Brush Range Management Committee, and the University of California Cooperative Extension Office for Mendocino County. In addition several private landowners either are, or soon will be involved in this study.

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The primary study area is in the northeastern portion of Mendocino County, immediately east of the town of Covelo. As described in our earlier progress report we were successful in acquiring, at the start of this study, each of the following kinds of remote sensing data for the study area and its immediate environs:

(1) Landsat imagery; (2) Landsat digital data; (3) high altitude infrared color photography; and (4) standard "resource photography" of the type being used throughout much of the United States by various federal and state government agencies.

Primarily through the use of digital Landsat data, RSRP personnel completed a computer classification of vegetation types for this pilot study area and presented it in image form to the above mentioned cooperating groups and agencies. Also provided was ancillary information with respect to the soils, geology, topography transportation routes, property boundaries and property ownership for the area. Based on a recent evaluation that was made of these materials by the participating groups, modifications in the Landsat-based classification scheme now are being developed by RSRP personnel.

Most of our action-based efforts to date have been concentrated within 2 portions of the 80,000-acre pilot study area (known respectively as the "Murphy Creek Drainage" and the "Thatcher Creek Drainage"). Preliminary measures were being taken in the Thatcher Creek Drainage, even at the inception of the present project, to reduce the amount of fuel (and hence the fire hazard) in decadent brushfields of chamise. During the period covered by this Progress Report we have been able to provide increasing amounts of remote sensing-derived information about the nature of these brushfields to those charged with brushfield manipulation in the area. An examination of the photos appearing in Chapter 2 of this Progress Report, and of their supporting captions, will serve to illustrate the very significant extent to which resource managers in this area are using our remote sensing-derived information. All of these illustrative photos and captions have been reviewed by responsible officials of the agencies that are presently most concerned with the resources in this particular portion of the pilot study area. They have indicated complete agreement with our forthright claims as to the use they are making of the information that RSRP personnel are providing.

In Chapter 3, where work of the Geography Remote Sensing Unit on the Santa Barbara campus is reported, three remote sensing-related projects are dealt with, including the previously mentioned Case II Study.

The first of these seeks to use remote sensing data in prediction of watershed runoff in relation to water storage and flood control under the mandated jurisdiction of the Kern County Water Agency. This study has now progressed from the feasibility stage to one in which specific products are being produced through the application of modern remote sensing technology in order to meet the user agency's needs in a timely and cost-effective manner. As a measure of its satisfaction with GRSU's work to date, the Kern County Water Agency has authorized payment to GRSU of \$10,000 for completion of the computer-aided classification of some 10,400 Km² of mountainous watershed in Kern County. An additional \$1,000 contribution in KCWA personnel time also is being provided. In representative comparisons of the cost of vegetation mapping per topographic quadrangle, remote sensing-aided methods, based primarily on information derived from Landsat computer compatible tapes, have proved to be ten to fifteen times less costly than conventional ground survey methods.

A second GRSU study dealt with in Chapter 3 of this Progress Report pertains to the use of remote sensing data as an aid in estimating the fuel moisture content of woody vegetation. The U.S. Forest Service has shown great interest in this project and has cooperated by (1) providing ground-based fuel moisture and climatological data for the test areas and (2) purchasing five Landsat computer compatible tapes of these areas. Based on results to date the Forest Service has stated its desire to replace the present system of collecting fuel moisture data on woody vegetation with a system that would use Landsat reflectance data in conjunction with readily available local climatological data.

The third of these GRSU studies deals with the mapping of cotton fields from Landsat imagery. Cotton is California's most valuable field crop and since 1974 California has been the leading producer of cotton. Because of cotton's role in both the state and national economy (it being

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the fifth most valuable U.S. export crop) the control of insects and other damaging agents that affect cotton yield is a major agricultural concern. The biggest threat to cotton in California is the pink bollworm, considered to be one of the world's most destructive cotton pests. A first step, each year, in controlling the pink bollworm and other cotton pests is that of mapping all fields in a vast agricultural basin that are currently being devoted to the production of cotton. Already the remote sensing-based techniques used by GRSU personnel in mapping cotton fields range from 86 to 92 per cent in accuracy. With the cooperation from several interested agencies, GRSU personnel are continuing their highly promising cotton-mapping studies within the Wheeler Ridge-Maricopa Water Storage District in southern Kern County, California. It is anticipated that, during the 1978 growing season, GRSU personnel and their cooperators will be able to make an operational test of these techniques leading to the acceptance of them by the user agency.

In Chapter 4, work of the remote sensing group on the Riverside campus is reported upon. Their overall objective is to apply remote sensing to resource management problems in southern California.

The major study of the Riverside group deals with resources of the California Desert, a vast (25 million acre) area which covers approximately one fourth of the entire state of California. Management of resources in this area has been a major concern of several county, state and federal agencies for the past ten years. Under the "BLM Organic Act" which was passed by Congress in 1976, BLM is required to develop a comprehensive management plan for this area by the year 1980. Because of the time constraints, vastness and the remoteness of the area, conventional ground survey methods cannot feasibly be used. The Riverside group is in the process of developing remote sensing-based techniques and transferring the technology to user agencies and especially to the Desert Planning Staff of the BLM for their use in completing their surveys of the entire California Desert. The three initial studies are of the sand dunes, the landforms and the development of a technique to identify candidate wilderness areas within the California desert. With respect to the last of these, NASA U-2 photography proved to be the most valuable source for showing primitive roads, mining features and isolated buildings.

A second undertaking of the Riverside group seeks to use modern

remote sensing technology in the making of a citrus tree census for a large area in southern California. The California Citrus Advisory Board currently is reviewing results to date with a view to its offering continued cooperation.

Similarly, the Riverside group is responding to the concern of several California state agencies, as well as that of agencies of San Bernardino County, over the loss of prime agricultural lands to urbanization. Obviously, a first step in relation to that concern is how best to monitor the rate and location of such a loss. The Riverside group is in the process of demonstrating to these concerned agencies the uses and limitations of remote sensing in relation to this monitoring requirement. Numerous letters from user agencies which react favorably to these various activities of the Riverside group have been received during the period covered by the present report. Four such letters are included in that group's report as an addendum to Chapter 4. The letters are from knowledgeable officials in four user agencies, viz. the California Department of Water Resources; the California Department of Transportation, the Riverside County Planning Commission, and the Bureau of Land Management's Desert Plan Staff.

In Chapter 5, two "special studies" are dealt with which fall within the purview of this grant. Special Study No. 1 deals with remote sensing as an aid to the identification of wildlife habitat in Mendocino County, California. Of particular interest to both Mendocino County and the California Department of Fish and Game is the identification of various kinds of upland game habitat, including those which can support wild turkey populations. Our limited work to date on this project is illustrated by the photos which appear at the end of Special Study No. 1 in Chapter 5 of this report.

Special Study No. 2 is titled "Remote Sensing of Dipteran Breeding Habitats." It represents a joint effort between our Remote Sensing Research Program at Berkeley and the Mosquito Abatement District of Lake County, California. The development of a remote sensing-based capability for locating and monitoring areas in Lake County that serve as breeding grounds for pestiferous insects is of great importance partly because such insects are jeopardizing the \$15 million per year tourism industry.

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In fact in Lake County this amount is second only to the income that is derived from that county's agricultural industry. As indicated by the photos and captions which accompany the Special Study No. 2 report, both Landsat imagery and U-2 photography, when supplemented by direct on-site inspection are useful in each of the following three ways:

- (1) in locating lakes, ponds and other dipteran breeding sources;
- (2) in estimating conditions that exist at each such locality; and
- (3) in determining the most suitable route for walking and/or driving to each such area.

In this study personnel of the Lake County Mosquito Abatement District (LCMAD) are providing the rationale, technical guidance and matching efforts by field crews, while RSRP personnel are initially providing the expertise needed for adequate interpretation of the imagery. It is anticipated that, in the near future, the LCMAD will be able to employ these techniques routinely, economically, and on a self-sustaining basis.

Resource management agencies in California currently are giving great emphasis to a relatively new activity known as "Coordinated Resource Planning." The potential for remote sensing is greatly increased because of this. Hence there is included at the end of this progress report an appendix which seeks to explain the concepts and considerations that are involved in that activity and how remote sensing can best relate to the coordinated resource planning activity of California, in general, and of Mendocino County, in particular.

APPENDIX A
SOME CONCEPTS AND CONSIDERATIONS INVOLVED IN
COORDINATED RESOURCE PLANNING

by
Robert N. Colwell

INTRODUCTION

In Chapter 1 of this report mention is made of the desire to translate one or more of our Case Studies into a demonstration of an activity that recently has come to be known as "Coordinated Resource Planning." Such an accomplishment would represent a very significant move toward our achieving a major objective in relation to our project viz. "to demonstrate that information derived from the use of modern remote sensing techniques can lead to the development and implementation of more intelligent resource management measures -- so that resource managers would then make remote sensing an integral part of their overall resource management process."

Coordinated Resource Planning is the term applied to action that involves the cooperative efforts of the various landowners and public agencies that are concerned with the land and resources in a given area, with the objective of bringing about improved management within that area. As stated in a recently published federal document entitled "Coordinated Resource Planning in California" . . . "Coordinated resource planning is a new approach to decision making, that is, how to use the land and resources available to best meet the needs and the responsibilities of the landowners of public agencies involved".

The approach that is employed seeks to use the best efforts and knowledge of everyone involved, -- private landowners, interested Federal or State Agencies and other specialists. As a group they inventory the planning area, analyze the information available, identify and define the objectives, evaluate the various management alternatives that are available, and arrive at management decisions which are acceptable and suitable. The program thus seeks to place total land use planning and resource management in a position of importance for the landowner or operator who must

make a living from the land. Simultaneously, it seeks to provide for the maximum multiple use benefits of national interest. Hence any effective demonstration, of the type that we envisage, would need to be conducted within an area that has a desirable mixture of private and public ownership. Furthermore, the demonstration most likely would be all the more meaningful if a rather wide variety of private and public ownerships (and associated resource management interests) were represented within the demonstration area. The northeastern portion of Mendocino County, (site of our Case I studies) is a very favorable one, not only in this respect but in many others as well.

SOME BASIC PREMISES INVOLVED IN COORDINATED RESOURCE PLANNING

Premise No. 1. You can't develop a realistic resource and land management plan until you know existing conditions, limitations and potentials of the area. Much of the required information may already be available, but it needs to be assembled, consolidated, and (in most instances) updated and augmented with the aid of information that is best derived through the use of modern remote sensing techniques, augmented with only limited amounts of direct on-site inspection.

Premise No. 2. To be useful the available information must be understood by all interested parties. Ordinarily this, in turn, requires that the present situation, limitations, potentials and problems are discussed freely so that all participants have a clear picture of opportunities and constraints within which the coordinated resource plan is to be developed.

Premise No. 3. The objectives must be clearly defined. Considerable skill usually must be exercised in accomodating the primary objectives of all of the concerned parties, and in synthesizing these into a clear statement of overall objectives, while at the same time allowing the necessary flexibility for attainment of individual or agency goals. The accomplishment of this difficult task can be facilitated if use is made of remote sensing derived products, such as aerial photographic enlargements, or mosaics made from high-flight photography, or (for very large areas) from space-acquired imagery. Such materials permit all parties to comprehend more clearly both the present situation and the various alternatives that are being proposed.

Premise No. 4. There must be an objective evaluation of alternatives. It is to be expected that with diverse interests there will be different opinions. Only by means of an honest expression of these opinions, followed by an honest appraisal of alternatives, is a compromise likely to be arrived at that will be acceptable to all parties involved.

Premise No. 5. Clear-cut decisions should be arrived at. No Coordinated Resource Plan should be considered complete until the decisions have been reached and expressed in terms that cannot be misunderstood. If there is to be a decision of responsibilities, there is all the greater need for clarity of expression in describing the nature of the duties and responsibilities of each participant. Without cooperation there is no coordination and consequently the objectives of the Coordinated Resource Planning efforts will not be achieved.

Premise No. 6. Opportunity must be provided for a subsequent revision of the Coordinated Resource Plan. Re-evaluation of the plan from time to time is necessary in order to keep the plan viable. Conditions change, needs change and objectives therefore may need to be revised. Consequently provision should be made for local planning groups to get together periodically to review accomplishments, acknowledge shortfalls, and develop future plans.

SOME SPECIFIC OBJECTIVIES OF COORDINATED RESOURCE PLANNING

Within California's wildland areas there quite commonly are 5 specific objectives of a Coordinated Resource Plan. It is doubly meaningful to quote these 5 objectives, verbatim, from the previously mentioned document, because it so accurately states what the objectives might well be in developing a Coordinated Resource Plan for our Case I Study Area in Mendocino County. These are:

1. Improve the quality and quantity of forage and habitat for domestic animals and wildlife.
2. Maintain and improve the harvest of forest products, compatible with other resource values.
3. Manage the watershed to prevent or reduce pollution, siltation and erosion.

4. Provide for maximum public benefit from the land and its resources, including recreation where practicable, and
5. Improve the economic status of the ranch unit involved.

SOME SPECIFIC STEPS INVOLVED IN COORDINATED RESOURCE PLANNING

The specific steps that are involved in coordinated resource planning may vary from one locality to another. It is considered relevant, however, to list here the steps that most commonly should be followed. In so doing we will be able to see more clearly that there are many points within this sequence of events, at which remote sensing is likely to be very useful. More importantly, perhaps, this listing will serve to emphasize that remote sensing of natural resource should rarely if ever be considered as an end in itself. Instead it should be considered as a tool which, if properly used, can facilitate wise resource management. Here, then, is a listing of such steps:

Step 1. Define the geographic area within which the coordinated resource plan is to be developed.

Step 2. For this area, identify the owners, agencies and other interested parties.

Step 3. At a meeting where all of these interested parties are adequately represented, obtain a list of the resource-related concerns and goals of each. Then, through group discussion arrive at an agreement as to which "overall objectives" are most important in light of these individual objectives. The resulting product is commonly known as the "Coordinated Resource Plan Objectives".

Step 4. In light of these objectives, define the necessary resource data base, i.e. the basic information that must be available so that specific plans can be developed.

Step 5. Determine how the required information is to be obtained. This, in turn entails a determination of (a) the amount and suitability of existing information; (b) the specific nature of the additional information that is required; and (c) the group or agency that will be responsible for acquiring the additional information.

Step 6. In conformity with the plan developed in Step 5, above, collect the additional information.

Step 7. Display all of the pertinent information on a common base, or otherwise in a readily comprehensible form. Quite commonly the use of a map or a photo-mosaic in conjunction with multiple information overlays constitutes the best means of satisfying this requirement.

Step 8. In view of the information that has now been acquired, consider the various resource management alternatives, including the cost effectiveness of each. Analyse these alternatives, comparatively, and select the ones that will be implemented.

Step 9. Based on the individual resource management measures that have been selected in step 8, develop in final form the overall coordinated resource management plan.

Step 10. In light of the capabilities and responsibilities of each participating landowner and agency, decide who will perform each phase of the overall plan and on what time schedule. In addition, if appropriate, arrive at cost-sharing agreements.

Step 11. Implement the plan in conformity with the previously agreed upon time schedule. Remote sensing frequently is useful throughout this implementation phase in directing work crews to the exact spots and via the most suitable routes, and also in monitoring and documenting the rate of progress.

Step 12. At suitable intervals after the implementation of any given aspect of the plan, monitor the results (e.g. the acceleration of tree growth following a thinning operation in a timber stand, designed to release the dominant and co-dominant trees; the increase in wildlife numbers following brushfield manipulation). As appropriate, and based on this monitoring process, revise or update the overall management plan and conduct Coordinated Resource Planning on a continuing basis.

SOME POTENTIAL BENEFITS OF COORDINATED RESOURCE PLANNING

1. One coordinated plan is likely to be more efficient and beneficial than several uncoordinated plans.

2. It reduces the chance of overlooking multiple use values of the overall area.

3. It provides an opportunity for all parties to present ideas and discuss the pros and cons of various management alternatives, before a final binding decision is reached. Axiomatically it provides all parties with an opportunity to see where and why adjustments and compromise are need and why some seemingly worthy ideas cannot be implemented.

4. It increases the participants' knowledge of various government agencies, their policies, their programs, and the reasons for each. As a result it is likely to result in increased public support of such agencies, policies and programs, and also improve working relationships among the agencies, themselves.

5. It is likely to provide more flexibility to ranch operators and more alternatives to problem solving than would be possible without the Coordinated Resource Plan.

SOME POTENTIAL COOPERATING AGENCIES WITHIN CALIFORNIA

There are at least 9 federal and state cooperating agencies within the state of California that are official participants in this program of Coordinating Resource Planning. They are worth listing, since every one of them is a potential participant in the event that we are successful in developing a Coordinate Resource Plan for our Case I Study Area. They are: Bureau of Land Management (USDI); Forest Service (USDA); Soil Conservation Service (USDA); California Resource Conservation Commission; Cooperative Extension, University of California; California Associations of Resource Conservation Districts; California Department of Fish and Game; California Department of Conservation; and California State Land Division. It is probable that involvement of personnel of our Remote Sensing Research Program of the University of California could be accomplished without adding to this list merely by having them participate through the University's above-listed Cooperative Extension program.